The 30th

Annual International Conference of ISDRS on Sustainable Development Research

Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood

PROCEEDINGS

June 10-14, 2024 | Kathmandu, Nepal

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Message from the Vice-Chancellor

With deep satisfaction and academic pride, I present this message as part of the proceedings of the 30th Annual Conference of the International Sustainable Development Research Society (ISDRS), successfully hosted in Kathmandu, Nepal from 10–14 June 2024.

Mid-West University was privileged to host this global event alongside Nepal Open University with Resources Himalaya Foundation as the secretariat, and esteemed national and international partners. The conference welcomed 300 participants from 47 countries, with 318 abstracts received from across five continents—making this event a truly global forum for sustainable development discourse.

Set against the stunning natural beauty of Nepal, the conference embraced the timely and powerful theme: "Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood." This theme reflected Nepal's unique ecological and cultural context and emphasized the vital interconnections between mountain ecosystems and oceanic health, from glacial rivers to coastal livelihoods.

The eleven conference tracks spanned a wide spectrum—from biodiversity and climate resilience to sustainable cities and digital transformation. Each track fostered vibrant academic exchanges and practical reflections. These proceedings now encapsulate that rich body of knowledge and represent a milestone in our shared journey toward sustainability.

We extend our heartfelt thanks to the ISDRS community, the organizing committee, and every contributor. It is our sincere hope that these proceedings will continue to serve as a valuable resource for scholars, institutions, and change makers working to realize the promise of the SDGs—locally, regionally, and globally.

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Prof. Dhruba Kumar Gautam, PhD
Vice-Chancellor, Mid-West University
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Message

It is with immense pride and pleasure that I share this message in the proceedings of the 30th Annual International Conference of the International Sustainable Development Research Society (ISDRS), held in Kathmandu from 10–14 June 2024.

As a co-organizing institution, Nepal Open University was honored to play a vital role in convening this globally significant conference—one that brought together over 300 participants from 47 countries, with 318 abstracts submitted from more than 50 countries. This remarkable gathering of scholars, scientists, development professionals, and students truly reflected the multidisciplinary and international essence of ISDRS.

The theme of the conference—"Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood"—deeply resonated with our national and institutional priorities. The dialogues underscored how sustainability is not merely a goal but a way of life—long practiced by indigenous communities. The rich discussions and collaborations explored sustainability from both natural and social science perspectives, bridging global aspirations with local realities.

Nepal's unique geography and cultural wealth provided an ideal backdrop for the diverse conference tracks—from climate change and energy to sustainability in the Himalayan region. These proceedings now serve as a lasting testament to that knowledge exchange and to the collective will to achieve the Sustainable Development Goals (SDGs) through research, innovation, and inclusive collaboration.

We are grateful to the ISDRS Secretariat, the organizing committee, and all contributing partners for their dedication. May this volume of proceedings continue to inspire scholarship, policy action, and global partnerships for a more sustainable future.

Professor Shilu Manandhar Bajracharya, PhD
Vice-Chancellor

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Preface and Acknowledgements

The International Sustainable Development Research Society (ISDRS) held its 30th annual international conference in Kathmandu, the capital of the Himalayan nation of Nepal. The conference marked a significant milestone in advancing the global sustainability agenda. Hosted in a hybrid format, the conference brought together over 250 participants from 47 countries, representing one of the most extensive international gatherings in the post-COVID-19 "new normal."

The conference was inaugurated by the Vice President of Nepal, while the Deputy Prime Minister and the Minister for Foreign Affairs participated in the valedictory session, underscoring the national significance of the event.

Nepal's new universities Mid-West University and Nepal Open University jointly hosted the conference. They established an inclusive academic platform by engaging five recently founded universities from across the country: Agriculture and Forestry University, Far-Western University, Madhesh University, Purbanchal University, and Rajarshi Janak University. This collaborative initiative laid the groundwork for stronger inter-university cooperation across Nepal.

In addition to the universities, the conference was supported by 12 key institutions, including the University Grants Commission (Nepal), the National Trust for Nature Conservation (Nepal), UNDP, and UNESCO. Serving as the conference secretariat, the Resources Himalaya Foundation played a central role in coordinating logistics and mobilizing resources.

The conference featured 220 research contributions across 10 thematic tracks, showcasing the interconnected and multifaceted nature of sustainable development. It highlighted the critical need for inter- and transdisciplinary collaboration, localized strategies, and inclusive approaches. Of particular significance was the strong participation of scholars from the Global South and women researchers, whose contributions emphasized the importance of addressing context-specific sustainability challenges and solutions.

The event called for the strengthening of research cultures in emerging academic institutions, improved science communication, and deeper engagement with issues of equity and planetary boundaries. These themes are especially relevant for Nepal—a Least Developed Country facing severe climate vulnerability. Melting Himalayan glaciers, rising frequency of wildfires, and increasingly erratic weather patterns are threatening livelihoods, particularly in rural farming

communities. The timing of the conference was pivotal, as Nepal aspires to graduate to a developing nation status amidst these mounting sustainability challenges.

The conference served both as a challenge and an opportunity. It identified the urgent need to build robust platforms and mechanisms for collaboration among key actors in the Global South and emerging economies, reaffirming their crucial roles in achieving the Sustainable Development Goals (SDGs).

One of the key outcomes of the conference was the adoption of the Kathmandu Communiqué, which emphasized the importance of integrating the SDGs with planetary boundaries and understanding the socio-economic dimensions of sustainability—particularly equity, inclusivity, and the impacts of sustainability transitions on vulnerable populations.

We sincerely thank all partner organizations, volunteers, researchers, and scholars whose commitment and contributions were instrumental in making this conference a meaningful and memorable milestone in the global dialogue on sustainable development.

We extend special appreciation to the track reviewers, paper and poster presenters, and all participants, whose active engagement played a vital role in the conference's success.

Prof. Sjors Witjes, PhD
President
ISDRS 2024

Prof. Dinesh Bhuju, PhD
Convener
30th ISDRS Conference 2024 Kathmandu

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Track 1 Sustainability and Science

1a. Theoretical Approaches

Abstracts

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Need of Accounting Sustainable Development Goal Interactions: Insights for a Systematic Review

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Abstract

Implementing the 2030 Agenda, with its 17 goals and 169 targets, presents a multifaceted challenge in terms of context-specific prioritization and understanding the interconnections among Sustainable Development Goals (SDGs). It is widely acknowledged that focusing efforts on achieving a single goal or target may result in trade-offs with other objectives, while also creating opportunities for synergies to emerge. If the nature of interdependence between the goals is not considered, there is a risk of producing conflicting results that could hinder progress toward sustainability. For this, an interdisciplinary yet systemic approach is required to maximize the synergies at different scales and sectors. As understanding the interactions demands an interdisciplinary approach, different ontological assumptions regarding each SDG become imperative. As there is a broad acceptance of the critical role of interactions within the SDG agenda, scholarly attention has been shifting towards investigating interactions as a separate field of scientific inquiry. Despite the target of policy coherence being realized through multiple studies, a critical knowledge gap remains in understanding how these complex interlinkages are addressed for policy designs and implementations across various sectors and associated social, economic, and earth systems. We aim to bridge this gap by conducting a systematic synthesis of the current literature on SDG interactions. The review involves comprehensive keyword search strategies across multiple databases, including but not limited to Scopus, and Web of Science. Furthermore, manual searching of key journals and reference lists complements the electronic search. The inclusion criteria prioritize peer-reviewed articles and policy documents published between 2015 and 2024. Focus is set on various empirical studies, theoretical frameworks, and methodological tools accounting SDG interactions. Relevant data from the selected studies are extracted and synthesized to identify key findings, themes, and trends. This investigation highlights the significance of comprehending SDG interactions, offering valuable insights into present approaches for policy design and implementation. Along with discussing the opportunities created, the synthesis also notes the challenges associated with it both direct and indirect interactions. The findings from the review yet again establish the complex dynamics at play in sustainability science and promote recognition for interconnectedness. Serving as a reference for researchers and practitioners in governance and policymaking, it will provide a crucial perspective on addressing synergies and trade-offs to enhance effectiveness in achieving SDG targets across disciplines.

Submission ID: 279

Organizing the Planetary Boundaries for Novel Entities: A Proposal for The Systematization of Knowledge

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Abstract

Initially referred to as the planetary boundary (PB) for chemical pollution, it was expanded and called "novel entities" (NovEnt), now including all "*new substances, new forms of existing substances, and modified life forms that have potential to* [produce] *undesirable geophysical and/or biological effects*". The myriad of entities that fall under this definition and the scale of the problem pose scientific and governance challenges. NovEnt encompasses more than one boundary, and we have probably already exceeded the safe threshold for it. However, there is the challenge of overcoming ignorance about the threats while the disruptive effects of NovEnt are not discovered until they become a potentially irreversible problem on a planetary scale. There are also potential additive and transgenerational effects for which current investigative methods are inadequate.

Different types of NovEnt also require a diversity of study strategies and methodologies. Understanding the dynamics and effects of these entities on nature and humans depends on field studies and laboratory representation of the complex interactions involved. It was not initially possible to establish the status for NovEnt, which was only formally proposed in 2023. Current definition has a logical and qualitative character, and it is virtually impossible to quantify this boundary or parts of it. These conditions encourage a proactive and preventive attitude towards NovEnt. To move forward, efforts are needed to organize knowledge on this PB. We propose (i) to systematize the available knowledge and establish a classification of the different types of substances, (ii) to adopt ecological approaches based on biogeochemistry, (iii) to include invasive alien species (IAS) in the NovEnt list. The inclusion is based on three criteria: *first,* like genetically modified organisms, they are new to the ecosystems where they are introduced. The former's success depends on human intervention, while IAS are successful on their own merit, but regulated by human factors. *Second*, like heavy metals and radioactive elements, exotic species exist in nature but are transferred from their contexts to others in which they are new and can produce adverse and unpredictable impacts, cause species extinction and impact human health. *Finally*, IAS are considered a global threat to biodiversity, despite not being part of any PB.

In conclusion, the complexity of NovEnt poses scientific and governance challenges. It is necessary to systematize knowledge about NovEnt and focus studies on their behaviours and dynamics in ecological and human systems. To contribute to these tasks, we propose: (i) the identification and classification of NovEnt; (ii) the study of the biogeochemistry of NovEnt; and (iii) the inclusion of IASs in the list of NovEnt. SDGs related to the study topic: 2, 3, 9, 11, 12, 14, 15.

Full Papers

Submission ID: 72

Assessing Wet Deposition of Microplastics in Agricultural System of Poland with Implications for Agricultural Soil Contamination and Sustainable Livelihood

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Abstract

Concerns regarding the adverse impacts of microplastics on livelihoods have arisen worldwide. Rainwater and clouds could also be a possible source of microplastics in terrestrial and aquatic environments, including mountains and agricultural systems, which can impact the livelihoods of people who rely on these systems for their survival, such as farmers, fishermen, and tourism operators. Microplastics in rainwater can also accumulate in agricultural soil. This can lead to soil contamination and increase the chance of microplastics being absorbed into plant roots and affecting plant growth. Microplastics in the food chain have a direct impact on human health and different species on land. Sustainable development goals 3 “good health & well-being” and 15 “life on land” could be achieved by food production in a clean environment. The aim of this study was to assess the wet deposition of microplastics in agricultural areas of Poland as a possible source of contamination in the food chain. The methodology used in this research was protected both nationally and internationally, and PCT/IB 2019 /051,838 of March 7, 2019, is the code of the submitted request granted an international patent extension in several countries worldwide, together with the accepted Italian patent number 102,018,000,003,337 on March 7, 2018. The sampling duration was three months from Jan-2023 to Mar-2024. Results showed a high concentration of microplastics in rainwater samples from agricultural areas. The results were categorized according to the identified particle sizes, colors, and shapes. The data was presented using FTIR Spectrometry. This study provides valuable information on the extent and sources of microplastics pollution in Poland's agricultural system, which will help to design policies and strategies to reduce microplastics pollution, promote sustainable development, and protect public health. This research study has linkage with SDG 15 and 3. The methodology and findings of this research can be used to assess microplastics impacts on livelihood, ocean and mountains worldwide and will help to plan strategy to achieve sustainable development goals.

Introduction

Microplastics are considered as a significant threat to the environment, particularly in agriculture system by affecting soil quality, microorganisms, crop production, and ultimately affecting the human health. Microplastics have been identified almost everywhere on the earth including remote areas. Few studies have shown the concentration of wet deposition of atmospheric microplastics but still we are not sure about the exact transportation flux of these tiny particles. Atmospheric washout with rain could be a potential source of microplastics deposition on agricultural land. The current research study focuses on wet deposition of atmospheric microplastics on agricultural land as possible sources microplastics contamination in agricultural soil of Poland.

Recent concern about microplastics in rainwater has arisen among researchers. MP in the clouds and rainwater can be an important source of microplastics transportation from one zone to another zone (Pirsaheb, 2020, p. 1-14). Since it's a quite new area of research, it's essential to understand all the possible ways of microplastics precipitation with rainwater on the ground, especially on agricultural soil (Xiang, 2022, p. 126843). It can lead to soil contamination and increase the chance of microplastics to get adsorbed on plant roots (Saud, 2023, p. 100298). There are some governmental strategies for the reduction in marine microplastics debris, but still there is a big gap between strategies and implementation (Onyena, 2021, p. 15-46).

With the attention continuously being paid to microplastics pollution in marine and aquatic ecosystem, the presence and impacts of microplastics in terrestrial ecosystem, particularly in the agricultural soil are less understood with considerable attention to work for better understanding. Agricultural soil is considered very important not only for food production but also for maintaining the ecological balance, keeping the ecological diversity, and supporting sustainable livelihoods. Tiny particles of plastics have ability to penetrate deep into the soil. This penetration of microplastics in agricultural soil raises concern about the soil health, crop production, and potential transfer of micro pollutants with biomagnifications into the food chain.

Rainwater is known as an important pathway for the deposition of microplastics on agricultural land (Brahney, 2020, p. 1257-1260). Wet deposition by rainwater enables the microplastics cycle in terrestrial, aquatic and atmospheric environments (Huang, 2021, p. 124399). Microplastics comes from households and industries that can directly go into the ecosystem, especially in air. From household micro pellets from air fresheners, sprayes, toothpaste, beauty products, and especially laundry can be directly released to the ecosystem (Yusuf, 2022, p. 118421). Degradation of plastic bottles, finishing nets and other plastic products can also lead to the secondary source of microplastic release to the atmosphere (Okeke, 2022, p. 100402). In the past few years, especially with the Covid 19 outbreak, the demand for single use plastic has increased (Adyel, 2020, p. 3114-1315).

Poland with its diverse soil types and agricultural and farming practices serves as an ideal case study to examine the microplastics issue in agricultural soil. Poland agricultural sector contribute a big portion in country economy. Although, the rapid increase of plastic material usage in agricultural practices and use of fertilizers, coupled with urban and industrial activities could be a big source of these soil contamination, but we are trying to understand the pathway through which microplastics can enter into the agricultural soil via wet deposition. This study particularly focuses on Poland, a country known for extensive agricultural activities. The main objective of this research study is to investigate the wet deposition of microplastics and its implications for agricultural soil contamination. This research will contribute to understand the extent wet deposition as a possible source of microplastics contamination in soil. This study will help to better understanding the extent and impacts of wet deposition of microplastics pollution in agricultural soil. With better understanding of problem, we can establish strong strategies to mitigate its effects and promote sustainable agricultural practices. To achieve these objectives, study employs a multidisciplinary approach involving field sampling, laboratory analysis, and Screening Electron Microplastics and FTIR data modeling. Rain water and soil sample was collected from different locations, particularly representing different levels of industrial and farming practices. Advance microscopy including SEM and FTIR were used to identify and quantify microplastics in both samples.

Literature Review

With new discoveries including the presence of microplastics in remote areas, ocean depth, and snow, micro and nano plastics studies referring to the new trending research (Dehuat, 2019, p. 346-359). Due to their toxicity and physicochemical properties, microplastics are considered as hazardous substances and getting attention from researchers. Microplastics are commonly referred to substances between the size ranges of 5 mm to 1 µm (Allen, 2022, p. 100057). Microplastics can be present in any form including, filaments, fibre, film, fragments (Shurti, 2021, p. e00123). Due to their physicochemical properties these materials never degrade easily and remain in the environment for many years and possess significant impacts on human health as they can accumulate in the food chain (Yang, 2021, p. 153511).

Current projections illustrate approximately 250 million tons of plastic will be deposited into the ocean by 2025 (Jambecek, 2015, p. 768-771). Although microplastics on land and surface water will remain suspended and will be re-suspended into the atmosphere. The weather conditions such as rain, wind and snow will serve as potential sources of microplastics deposition on different landscapes (Li, 2021, p. 116833). With this endless cycle microplastics from the terrestrial environment will be suspended into the atmosphere and washed away in the aquatic environment referred to as the plastic cycle (Rilling, 2020, p. 1430-1431).

Different strategies were used in different part of the world for advance modeling. In Eastern China filter was examined directly using a micro-Raman spectrometer (HR Evolution, Horiba, France), with size detection limit of ~ 1 µm. In southern China, for the preliminary screening out of MP, they used stereoscopic microscopy (Olympus SZX10, Japan). Later, Micro-FTIR analysis (Nicolet iN10, Thermo Fisher, U.S.A.) was used for compositional verification of suspected MPs (Yuan, 2023, p. 120113). In southwest England, all filters were examined under a Nikon SMZ800 stereomicroscope fitted with a 1x Achro objective (attaining a magnification up to 63 X) connected to an Olympus SC30 camera operated by Olympus Stream software. In southwest Iran, filter was analyzed with a binocular microscope (CarlZeiss) at up to 200 x magnification, with 250µm. For the visualization of polymers, they used ImageJ software. In India Bihar State, microplastics visual inspection happened under optical microscopy (Axiocam 503, Zeiss).

Table 1. Case studies based on wet deposition of microplastics with precipitation on different parts of the world

No.	Study Area	Sampling Location	Coordinates (Latitude & Longitude)	Sampling Period	Duration
1	Eastern China	Shanghai	(121°30′17″N, 31°17′4″E)	Sept 2019 - June 2020	10 months
2	Southern China	Guangzhou	(22°26′-23°56′N, 112°57′-114°03′E)	Jan - Dec 2021	11 months
3	Southwest England	Plymouth	(50.3751 N, −4.1385 E)	Nov - Dec 2021	42 days
4	Iran	Shiraz	(29.61998°N, 52.47418°E)	18th Jul 2021	30 minutes

No.	Study Area	Sampling Location	Coordinates (Latitude & Longitude)	Sampling Period	Duration
5	India	Patna, Bihta (Bihar State)	(25°32′01″N, 84°51′02″E)	Jun - Oct 2022	5 months
6	America	Bahia Blanca, Argentina	(38°46′37″S, 62°16′1″W)	Mar - Dec 2021	10 months
7	India	Kochi, Kerala	N/A	Oct 2019 - Sept 2022	100 days
8	America	Colorado	N/A	Jan - Aug 2017	8 months
9	Japan	Mt. Oyama	(35°26′N, 139°37′E, 1252 m a.s.l.)	Jul - Aug 2022	2 months
10	Japan	Mt. Fuji	(35°35′N, 138°73′E, 3776 m a.s.l.)	Jul - Aug 2022	2 months
11	Japan	Mt. Tarobo	(35°19′N, 138°48′E, 1300 m a.s.l.)	Jul - Aug 2022	2 months

Methodology

Present study's methodology includes multiple procedures designed to properly evaluate the wet deposition of microplastics in agricultural soils. The methodology used in this research was protected both nationally and internationally, and PCT/IB 2019 /051,838 of March 7, 2019, is the code of the submitted request granted an international patent extension in several countries worldwide, together with the accepted Italian patent number 102,018,000,003,337 on March 7, 2018. The sampling duration was three months from Jan-2024 to Mar-2024. The methods for sample collection, laboratory analysis, and quality control procedures are explained in this section.

Study Area

Study was conducted in Poland mainly in Wroclaw Klodzko region. As per topographical features of land two different landscapes were chosen in this research study. Selected sites included both traditional farming practice based rural area and region closer to urban and industrial area. These regions were selected to represent agricultural practices and to provide comprehensive overview of microplastics contamination in agricultural soil.

Figure 1. Sampling sites for the analysis of micorplastis quantification in rain and soil samples

Table 2. Dates specifications for both samples

Rainwater	Soil	Sampling Date
RW-1	S-1	23/Jan/2024
RW-2	S-2	28/Jan/2024
RW-3	S-3	19/Feb/2024
RW-4	S-4	24/Feb/2024
RW-5	S-5	5/Mar/2024

Abb. RW: Rainwater, S: Soil Samples

Sample Collection

Rainwater sample collection

Standardized rainwater sample collectors were used to collect the rainwater samples. The location to place these collectors were away from the direct sources of microplastics including industrial and urban area in open field. The collectors were designed for capturing all particles including microplastics and particulate matter coming with precipitation from the atmosphere.

Soil sample collection

Locations, where rainwater collectors were places, soil samples were collected from the same locations. To avoid contamination and following the standard, soil samples were collected from the top 5 cm of soil profile using stainless steel trowels. Multiple samples were collected from each site to ensure representativeness and were stored in pre-cleaned glass containers for laboratory analysis.

Lab Procedures

Wet sieving protocols

Samples were passed through sieve size 1.8 mm for separation of large particles and collected in a beaker. Sieves were raised with distilled water to make sure all microplastics particles passed through it.

Digestion process

Hydrogen peroxide (H2O2) was used for removal of organic contamination from the samples. Each sample was heated to a standard temperature of 150-degree celsius for 20 minutes. Once the sample showed bubbles 10 g of H2O2 that is 10% of the sample volume were added into the samples for digestion process. Beakers with a capacity of 800 ml were used and weighted before and after putting the sample.

Vacuum filtration system

Samples were undergone vacuum filtration after digestion for effective separation of microplastics form liquid phase. Membrane filter with pore size of 0.25 µm were used for capturing of microplastics from soil and rainwater samples. After vacuum filtration membrane filter were placed and examined under Screen Electron Microscope (SEM) and Fourier-Transform Infrared Spectroscopy (FRIT) analyzer for further analysis.

Figure 2. Vacuum filtration and sample preparation procedures.

Quality and control protocols

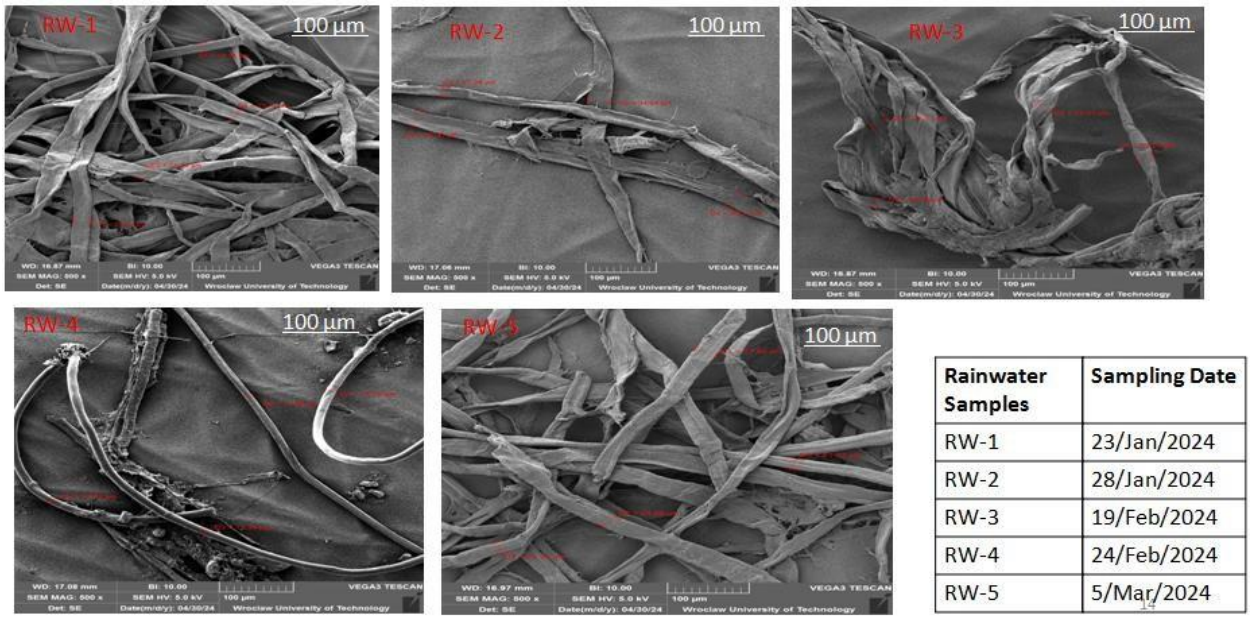
To avoid the external contamination all plastic wears were eliminated from the study. Lab equipment including beakers, funnels, and petri dishes were washed and cleaned with distilled water with 20% alcohol to remove all possible contaminations from experimental equipment. Beakers were covered with glass led throughout the experiment. Throughout the analysis all the samples were closely monitored for quality control.

Results

Identified Microplastics in Precipitation

Microplastics were categorized based on size and shape of the microplastics using Screening Electron Microscope (SEM) and Fourier-transform infrared spectroscopy (FTIR). Diameter of all microplastics

analyzed by SEM is shown in figure 3. Largest microplastics size identified in precipitation was 0.7µm and the smallest was 0.40µm were shown in finger 4.



Rainwater Samples	Sampling Date
RW-1	23/Jan/2024
RW-2	28/Jan/2024
RW-3	19/Feb/2024
RW-4	24/Feb/2024
RW-5	5/Mar/2024

Figure 3. SEM analysis for the rainwater samples from different locations

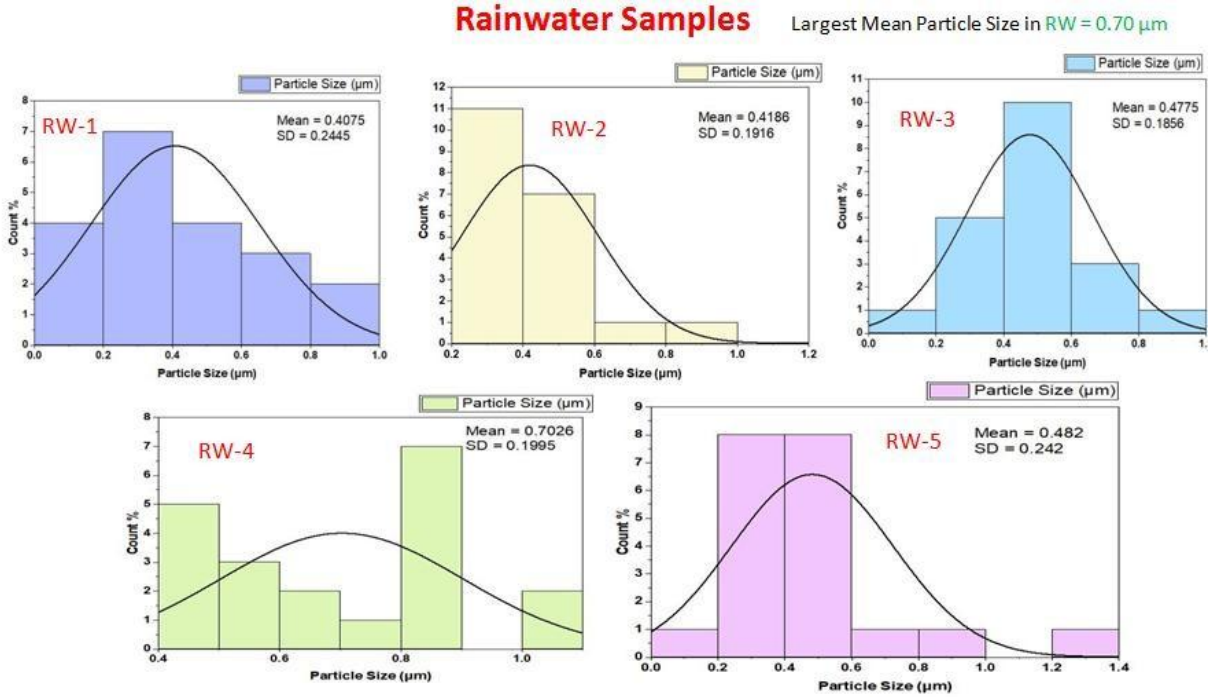


Figure 4. Particle size distribution of microplastics in different rainwater samples

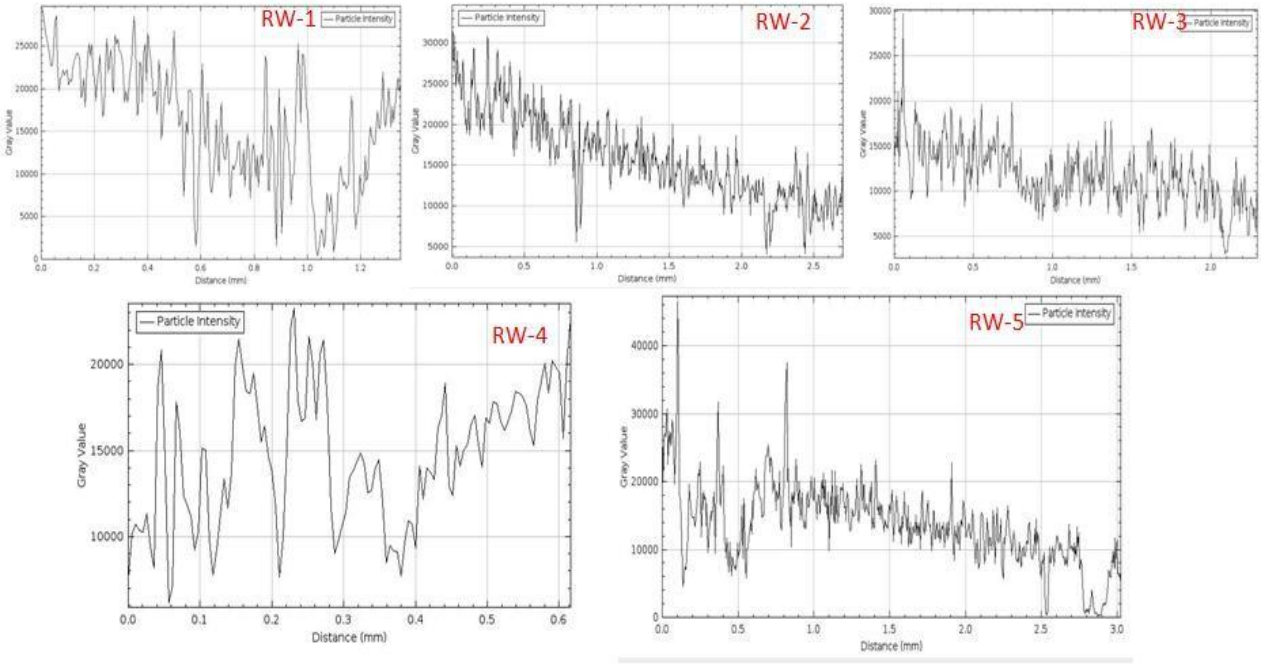
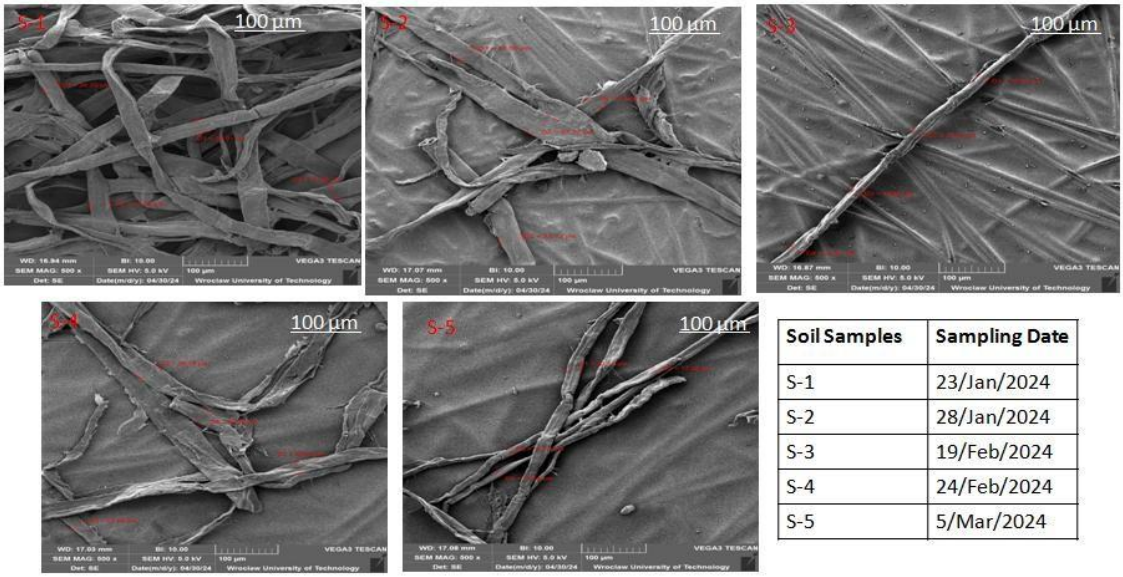


Figure 5. Particles gray value with intensity by FTIR analyzer in rainwater samples

Identified Microplastics in Soil

In most of the samples microplastics size found in soil were larger than rainwater. The largest microplastics size found in soil sample were 0.92µm and the smallest were 0.54µm. The largest particle size was found in S-5 and smallest was in S-3.



Soil Samples	Sampling Date
S-1	23/Jan/2024
S-2	28/Jan/2024
S-3	19/Feb/2024
S-4	24/Feb/2024
S-5	5/Mar/2024

Figure 6. SEM analysis for the soil samples from different locations

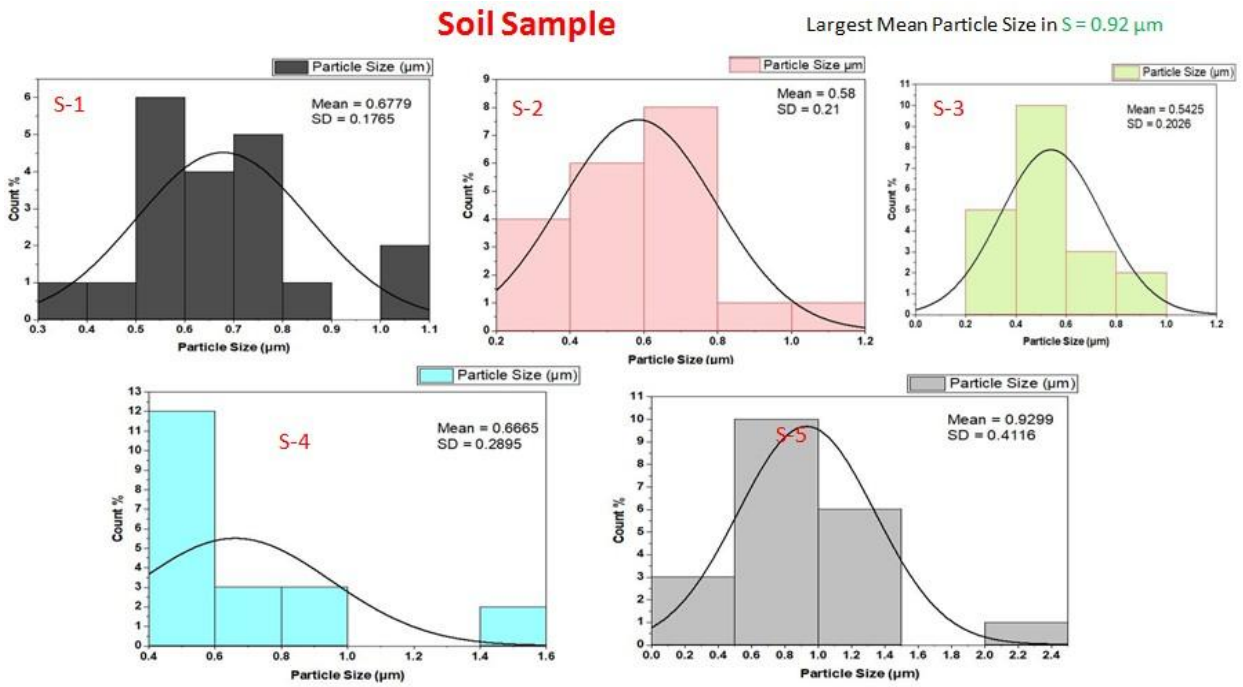


Figure 7. Particle size distribution of microplastics in different soil samples

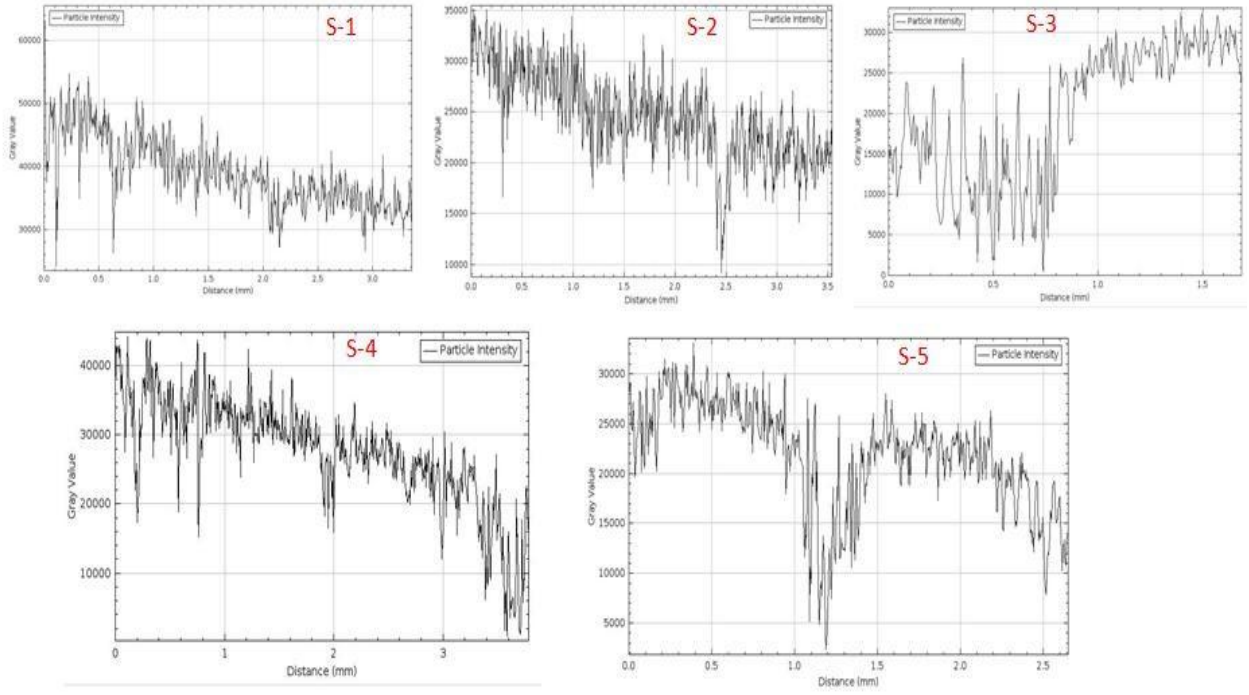


Figure 8. Particles gray value with intensity by FTIR analyzer in soil samples

Deposition Rate

Based on the deposition trend of microplastics first sample, collected on 23rd Jan 2024 contained the highest number of microplastics 28 particles/ m^3. Sample RW-2 collected on 28th Jan 2024 contained the least amount of microplastics 5 particle/m^3 in wet deposition. In soil samples S-4 contained the highest amount of microplastics 340 particle/ m^3 and S-3 contained the least amount of microplastics 110 particles/ m^3. Detailed of microplastics found in each sample based on number is provided in table 3.

Table 3. Microplastics quantification based on deposition rate and soil contamination in different samples.

Soil Sample	Rain Sample	Wet Deposition of Microplastic (Particles/m^3)	Soil Contamination (particles/mg)
S-1	RW-1	28	283
S-2	RW-2	5	198
S-3	RW-3	11	110
S-4	RW-4	7	340
S-5	RW-5	20	288

Correlation between Deposition Rates and Soil Contamination

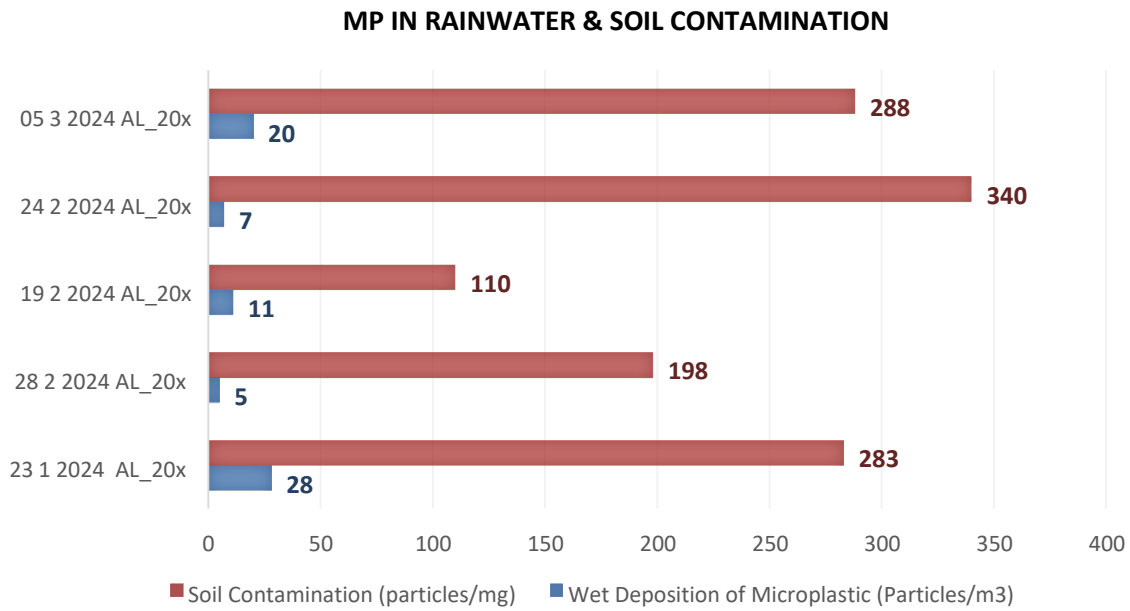


Figure 9. Correlation between micorplastics abundance in rain and soil sample.

Conclusion

Abundance of Microplastics found in all samples. Largest mean particle size with abundance in rainwater samples was 0.70 µm and 0.92 µm in the soil samples. Soil sample contain more microplastics than rainwater sample. This research study contributes in scientific knowledge on microplastics abundance in atmosphere and deposition with rainwater on different landscapes, including agricultural land. Data

presented based on real time sampling and analysis of rainwater in Poland. Further studies needed to understand the mechanism of microplastics transportation cycle.

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1b. Research Methods and Methodologies

Abstracts

Submission ID: 14

Mutual Enforcement between Fundamental Values and Conceptions of Sustainability

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Abstract

Since it was introduced in the Brundland Report in 1987, the term *sustainability* gradually increased its presence and exploded into popularity after the Sustainable Development Goals (SDGs) were adopted in 2015. The term is now sprinkled everywhere, from product advertisements by private companies to tabloid shows on TV, as if it were a fashion icon to demonstrate the sensitivity to global issues. However, there is no clear consensus on what the term *sustainability* actually refers to, nor is it clear what values are held and acted upon by those who use it. On the other hand, regardless of how the term *sustainability* is used, fundamental principles and values that people rely on in judging the correctness of their and other people's behavior regarding the symbiotic existence of humans and nature are rooted in the societies in which individuals live.

Fundamental values, recognition of issues in front, their perceived solutions, and actions to solve such perceived problems are all related but different layers of the cognitive process. Based on this understanding, in this study, the author tries to capture the relationship between people's conceptions of *sustainability* and fundamental values based on which people make ethical judgments and decide their acts on various issues, including those for *sustainability.* In her earlier study, which conducted a quantitative topic modeling using large-scale web-based texts as data, the author identified diverse connotations attached to the concept of *sustainability* depending on the backgrounds of the people who use it and their motivations. This past study came up with a list of phrases and words that appeared frequently in close connection with sustainability. The current study uses this list of issues and themes identified through the quantitative topic modeling as questionnaire items.

The questionnaire survey was conducted in February 2023 and distributed online to 206 participants in the Philippines and Kenya. These two countries were selected as the samples for the trial survey for being English-proficient societies in two different regions – Asia and Africa. The questions asked respondents to rate different themes and issues related to sustainability, together with their core values, ideological tendencies, and personality. The data from this questionnaire is then linked to the items from the large dataset from the World Value Survey (WVS) 2023, in which the Philippines and Kenya also took part. The WVS is a global research project that explores people's values and beliefs, how they change over time, and what social and political impact they have. There are also question items about people's values about development, co-existence with others, and utilization of limited resources.

Data will be combined from the questionnaire based on the *sustainability*-related topic models and items adopted from the WVS and examine the relationships among people's fundamental values, their conceptions of sustainability issues, and perceived solutions.

Submission ID: 20

Sustainability, Development and *Différance*

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Abstract

Deconstruction is a critical reading technique proposed by Jacques Derrida (1930-2004). This technique analyses the internal tensions of a discourse, exposes its inherent complexity and, as a result, casts new light into the addressed issue. In this presentation, I propose a deconstructive reading of the concepts of 'sustainability' and 'development', as used by the United Nations in the 2030 Agenda for Sustainable Development, and explain them in terms of identity. The term *différance*, coined by Derrida, combines the terms *différer* (differ in French) and *différence* (difference in French). Derrida uses it to highlight the contingent and elusive character of the meaning of words: every word finds its meaning by differentiating itself from others (*différence*) and by indefinitely postponing the fullness of its meaning (*différer*). These characteristics are noticeable in the case of the terms, 'sustainability' and 'development'.

In UN documents, sustainability refers to the idea of making use of resources in the present in a way that allows future generations to meet their needs as well. The very definition of sustainability subsumes the meaning of the concept to a future (*différer*) which, by definition, is unknown (we will never reach it, otherwise it would cease to be future). At the same time, the UN constructed the meaning of sustainability as a counterpoint to the concept of unsustainability (*différence*): first, we know what unsustainability is (a central characteristic of modern societies); then, sustainability is conceptualised as the opposite to unsustainability. The same logic works within the concept of development in UN documents. On the one hand, it is a concept that always points to a future where the present problems are solved (*différer*). On the other hand, the concept of development was born as a counterpoint to that of underdevelopment (*différence*): in the 1950s and 1960s, the United Nations first focused on underdevelopment, then theoretically defined development.

This presentation analyses the context where these concepts were articulated into UN discourse and shows them as symptoms of the transitions that the world is going through. In brief, development played a key political role during the 1950s, when the capitalist West aimed to take a centre position in world politics – as opposed to the underdeveloped and/or communist 'other' (*difference*) – and to show capitalism (democracy, freedom) as the way to a better future (*différer*); whereas sustainability emerged in the 1980s and 1990s, and gained momentum in the 2000s and 2010s, when the capitalist West assumed that it was not the centre anymore – the West is unsustainable: one 'other' among many unsustainable others (*difference*) – and that capitalism was an endless scape forward, looking for an unreachable promised future (*différer*). The presentation does not focus on any SDG in particular. Rather, it offers a general reflection about the inherent complexity of global sustainable development strategies. 'Development' and 'sustainability' are presented, not as the solution to our global problems, but as (identity) discursive tools intended to make sense of (grasp, hold, control) an ever changing and incommensurable reality – our world.

Submission ID: 44

The Evolution of Sustainability Discourses: A Deconstructed Reading

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Abstract

Sustainability has become a widely accepted and adopted discourse, taking on multiple meanings and uses over the years. This has enriched the discursive scenario but has also resulted in sustainability's characterization as a vague, ambiguous, empty, and contested term, which poses challenges to its representation and understanding (Salas Zapata & Ortiz Muñoz, 2018; Farley & Smith, 2020, Billi, Mascareño, & Edwards, 2021; Thompson & Norris, 2021). To gain insight into how sustainability is represented and constructed within the societal discourses, (Michaud, 2018; Khan Malik, 2021), this research employs Jacques Derrida's deconstruction double reading strategy. By applying the double reading strategy, this research looked at eight documents from 1987 to 2021 that have influenced the discursive landscape across multiple dimensions, including environment, economy, society, culture, religion, and politics.

The double reading strategy enables to capture of the discursive scenario of texts and involves two 'gestures' or moves (Derrida, *Limited Inc*., 1988, p. 21). The first, known as 'double commentary', consists of the abstraction of the authorial and textual intentions of the texts (*vouloir dire*) (Derrida, *Of Grammatology*, 1969, p. 158), which was carried out using qualitative content analysis as an auxiliary method. This gesture was followed by a second reading, known as 'deconstructive reading,' which examined the binary oppositions, *differánces*, aporias, and omissions within the texts (Derrida, *Writing and differánce*, 1967, pp. 229-230). The use of deconstruction provided a reading strategy for understanding sustainability discourses. The double reading strategy has revealed the evolution of sustainability, progressing from the initial Brundtland report which defined sustainability from a global perspective in 1987 to diverse contextual interpretations shaped by dimensions, goals, and authorial intentions. Most of the texts maintained a normative, scientific, and anthropocentric approach over time, except for the religious document *Laudato Si.* This research also found prevalent economic and political structures based on capitalist foundations and a democratic model, along with a strong political inclination beyond governance and regulatory frameworks. An increasing trend toward adopting a broader social, cultural, and ethical agenda was also observed, as well as a shift from apocalyptic narratives to less radical discourses that still emphasized the urgency, immediacy, and challenging nature of sustainability. Despite the adoption of a more inclusive and equitable perspective, the misrepresentation of certain actors, such as indigenous groups, continued in all discourses.

Overall, applying the deconstructive double reading strategy confirmed that sustainability is a multidisciplinary and multidimensional discourse that has, however, transcended to a transdisciplinary one, where practices and behaviors play an important role. The results also indicate that sustainability is influenced by the dimension in which it is rooted and is dependent on spatial and temporal contexts, as well as the authorial intentions that interpret it. As a result, it can be concluded that sustainability is a polysemic, *iterable*, flexible, multifaceted, and adaptable discourse.

Submission ID: 180

Critical Realism as a Methodology for Sustainability Research: Reflections on Circular Economy-Related Applications

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Abstract

Sustainability research is fundamentally driven by an interest in learning from experience to identify and implement change, as well as to identify new areas of research out of academic interest. Critical realism has been identified as a useful research methodology in sustainability, proposed both as an approach to reflexivity (Nastar, 2023) and as a driver for change (Schoppek, 2021). Presently, critical realism is undervalued and under-utilised in a field more given to objectivist approaches which comprises compromise between research approaches driven by objectivity and those explicitly pursuing constructionist approaches. The former, typically quantitative, can be overly swayed by a search for representativeness (missing the lessons from detailed case studies, for example). Whilst constructionist approaches (qualitative methods, emphasizing subjectivity) draw out individuality and particularities at the expense of underlying influences. However, the latter can be critical in hindering the implementation of sustainability initiatives. This paper seeks to increase awareness of critical realism, by reflecting on learnings from its application to research on the circular economy, as an example of sustainability research. The research has investigated a number of distinct but inter-related issues (uptake of eco-design, collaborative resource-efficiency measures as economic development, working in a circular economy) with case studies predominantly in the UK. Research methods, which are not proscribed by critical realism, have included semi-structured interviews, questionnaire surveys and document analysis. Findings illustrate the usefulness of critical realism to address the underlying causal mechanisms relevant to a situation, e.g., that whilst circular economy (or other sustainability) initiatives might offer environmental gains, social/economic gains are more elusive these and contingent on circumstances. The reflections herein are useful both as a guide to lessons learned from the research as well as to benefits from the approach.

This paper is relevant to all the SDGs as critical realism could be applied to research into any of them. The examples presented here for illustration are relevant primarily to SDGs 8 (decent work), 11 (sustainable cities and communities) and 12 (sustainable production and consumption).

Submission ID: 311

To Grow or to Decelerate? Deconstructing the Pervasive Rhetoric of Green Capitalism

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Abstract

This presentation takes aim at any form of green capitalism that is predicated upon the simplistic, reductive notion that unfettered economic growth and expansion should be the ultimate goal of every society. Moreover, this transdisciplinary discussion also undermines the progress-regression binary behind the unsustainable idea of continual growth that reinforces free market solutions to the anthropogenic crisis instead of imposing limits to curb our *ecocidal* aggression against the remainder of the biosphere in the Anthropocene-Technocene. Drawing inspiration from Jacques Derrida's concept of *limitrophy*, Edgar Morin's complex theory, the deconstruction of dominant, *ecocidal* metanarratives by the ecolinguist Arran Stibbe, and the promulgation of degrowth by the philosophers Pierre Rabhi and Anne Frémaux, this thought experiment problematizes the viewpoint that it is *always* possible and preferable to find a way to grow the economy without destroying the planet that enables greenwashers to reinforce global, late-stage capitalism. Although Derrida's neologism "limitrophy" is primarily an attempt to dislodge the dichotomous thinking pitting humans against other animals in his posthumous ecological thought, the philosopher's efforts to "break down the traditional conceptual boundaries" through the philosophical exercise of limitrophy also implore us to reflect upon a "safe operating space for humanity" outside of the progress-regression duality lurking beneath the surface of the discourse of economic growth (Taylor 177; Rockström *et al.,* 472). In a similar vein, Morin's complex thought contests the oppositional thinking linked to "the euphoric image of Infinite progress" by wondering if it is time to "decelerate" (Morin 352, 332). The problem of "boundlessness" to which Morin refers is why the late philosopher-farmer Rabhi identifies "economic growth as a problem and not as a solution" (Pons 74). Building upon and expanding Rabhi's theories about degrowth, Frémaux beckons us to imagine a post-capitalist world in her seminal essays *La nécessité d'une écologie radicale* and *After the Anthropocene: Green Republicanism in a Post-Capitalist World*. Even if technological advances are certainly part of the solution, proponents of degrowth compellingly posit that only a radical paradigm shift regarding our impoverished concepts of development and progress can help us to avoid the impending ecological apocalypse.

Submission ID: 317

Identifying Gaps in Landslides Studies to Expedite Sustainable Development in Nepal

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Abstract

Nepal is susceptible to various hazards because of its geographical location within plate collision zone, complex hydro-meteorological condition and varied socio-economic dynamics. Every year, the country experiences over 7,000 hazardous events, leading to estimated annual losses of approximately 5 billion dollars. Among these hazards, landslides have a particularly severe impact, accounting for about 4% of Nepal's Gross Domestic Product (GDP). More than 500 landslides occur yearly, resulting in 36% of recorded fatalities in the country from these incidents. Despite the ongoing threat of landslides and other hazards, Nepal is in the midst of rapid development giving due consideration to linear infrastructures. The country is witnessing an increasing trend in constructing new roads, bridges, and irrigation canals even in remote areas, as well as the expansion of urban centers driven by growing population and internal migration. The construction of hundreds of roads without a systematic plan, involving slope cutting without sound geo-technical considerations, has made the slopes vulnerable, contributing recurring landslide. Additionally, climate change impact such as localized intense rainfall in earthquake-affected zones and rising temperatures leading to rapid ice melting contribute to the increased likelihood of mass movement hazards and flooding in glacially fed rivers. Given these risks, it is critical to identify and categorize landslide-prone areas to implement effective mitigation measures. Various government bodies, universities and international NGOs are engaged in mapping and analyzing landslide risks, yet their efforts often focus on limited areas or specific projects. Similarly, academic research by graduate students on hazards in Nepal often remains unpublished, contained within university departments or libraries as thesis work. Even though research and development in Nepal have advanced considerably, the country's development approach has yet to reach a point of sustainability. Several factors are causing this gap, such as inadequate hazard risk assessments, limited use of scientific data in decision-making and a general disregard for the actual ground condition. This study highlights the importance of collecting hazards data and analyzing their impact comprehensively to foster sustainable development in Nepal. It further emphasizes that bridging these gaps requires the promotion of sustainable development practices based on ground reality and governed by scientific insights. This requires a multi-pronged approach, including improved data collection, robust risk assessments, and cooperative socio-technological decision-making among various stakeholders including key decision makers. By implementing these measures, Nepal can progress toward a more resilient and sustainable future, reducing the adverse impact of landslides and other disasters on the nation's economy and its people.

Full Papers

Submission ID: 111

A Survey Experiment towards Localization of Sustainable Development Goals in Eleven Districts of Rajasthan, India

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Abstract

This qualitative survey experiment captures ground-level issues to help design effective strategies for the localization of Sustainable Development Goals (SDGs) at the village level. The experiment was conducted with 73 random participants including academicians, local villagers, NGO representatives, and officials from the United Nations working in 11 districts of Rajasthan, India, and is set to impact this region. Each study participant was given two questions to think through the lens of their district to identify a local development problem a local solution and propose an approach to the solution. Data from the experiment was analyzed, categorized, thematically arranged, and taken through multiple generative correlations as per the Kawakita Jiro approach. Multi-dimensional issues in local governance, lack of digital infrastructure, and non-availability of demographic and geospatial data of villages were prevalent. 65% of problems in the localization of SDGs were related to local governance issues where lack of proper information dissemination, illiteracy, and lack of community participation were significant. Multiple structural inequalities faced by women have also been revealed with 40% of the responses signifying issues related to inequities in access to education, 26% discussing the lack of secured public spaces and transport for women, and 20% focusing on the lack of participation of women in local governance as challenges to be tackled under target 4.1, 5.1, 5.2, 5.5 and 5.b of Goals 4 and 5 respectively. Proper information dissemination using digital technologies, employment generation, and multistakeholder integration were required to address these challenges. 71% of study participants emphasized the need for bringing together NGOs, SHGs, government institutions, development agencies, and villagers to achieve the targets of SDGs at the ground level in par with the multi-stakeholder partnership targets of 17.6 and 17.7 of Goal 17. The results of this study conducted in a spatially marginalized location of Global South bringing multiple stakeholders together stand relevant as an effective methodology that can be adopted to bring nuanced ground-level perspectives to enable data-based local policymaking in low and middle-income countries.

Introduction

The UN Sustainable Development Summit held in New York in September 2015 is a landmark event with the adoption of Transforming our World: The 2030 Agenda for Sustainable Development by the United Nations. It stands as a universal framework to guide human development initiatives while ensuring the planet's prosperity in the following 15 years. It includes 17 interlinked and interdependent goals and 169 targets that require collaboration at global, regional, and local levels ('Transforming our world: The 2030 Agenda for sustainable development', 2015).

This agenda succeeds the Millennium Development Goals adopted in 2000 which focused on achieving eight goals for human development including eliminating poverty, ensuring primary education, curbing

gender inequalities, reducing environmental degradation, improving health indicators, and building universal partnerships for development. However, Sustainable Development Goals (SDGs) move beyond clear boundaries of problems and anthropocentric perspectives to bring an integrated mutually dependent set of goals to enable holistic development across the planet.

Recent reports suggest that the achievement of the 2030 Agenda for Sustainable Development in the Asia Pacific region is lagging behind the estimated schedule by 32 years on all 17 Goals (*Asia and the Pacific SDG Progress Report 2024: showcasing transformative actions*, 2024). Though the SDG goals are universal their achievement will largely be a cumulative result of the development initiatives in local pockets. Hence, localization is an effective approach as it brings the subnational context to the nucleus to guide the setting of goals, implementation strategies, and measuring the progress towards SDG goals.

The cultural, political, and linguistic heterogeneity of developing countries like India poses significant challenges to localization (Sengupta and Sinha, 2022). There are inter-regional and intraregional variations in the development indicators within the country. This study tries to understand challenges in the localization of SDG at a regional level through the lens of different stakeholders working at the ground level in these regions. The study is set to impact the Thar Desert regions of Western Rajasthan. The state belongs to the category of empowered action group (EAG) states. EAG states are socio-economically backward states and lag in the demographic and epidemiological transition with high fertility rates, high infant and child mortality, maternal deaths, high population growth rates, and low literacy (*National Rural Health Mission*, 2005; Kumar and Paswan, 2021). As a spatially marginalized region with pressing human development issues, this study is timely and relevant to set direction for achieving the SDG goals in this region. The paper is organized into three major sections. The initial section is a current discourse on the localization of SDGs and the Kawakito Jiro method adopted for the study. The subsequent section discusses the methodology and data analysis protocol. The final section outlines the key observations from the study followed by the conclusions.

Literature Review

This literature review is organized into two major themes. The first discusses the concept of localization of sustainable development goals followed by its workflow in the Indian context. The second theme elaborates on the Kawakito Jiro technique and its applications.

Localization of Sustainable Development Goals

Localization of SDGs is a process that places subnational context at the center of achieving the 2030 Agenda. Localization marks a paradigmatic change from a top-up approach to a bottom-up approach. Context becomes an important parameter in setting goals and targets to designing implementation strategies and indicators to measure and monitor the progress (*Local 2030 - Localizing the SDGs*, no date). Besides, it is a collective non-linear process where larger SDG frameworks and regional and local governments need to work in an integrated manner to achieve the goals. It relates to how the larger SDG framework can guide local development policies and also how the local and regional governments through their bottom-up approach can contribute towards the achievement of SDG goals (*Roadmap for Localizing the SDGs: Implementation and Monitoring at Subnational Level*, 2016).

Analyzing the data and disaggregating it to implement corrective structural and procedural action is inevitable to implement SDGs and achieve grassroots development (Patole, 2018). Application of SDGs at the grassroots also reflects upon the need for an optimal environment to sustain micro climate to enable local development (Gunnarsdottir *et al.,* 2020). Ecological restoration takes a long time to achieve, therefore it is a very important parameter to enable a good environment to support human activity in the region (Hu, Wu and Li, 2023). Fisher and Fukuda-Parr (2019) asserts that localization of SDGs requires a balance while considering decentralized farming aspects, local indigenous culture, infrastructure development, and provision of humanitarian aid as required in distinct locations. Data on local sustainable solutions should also be complemented with the top-down approaches of the governments of the country and state (Reuter, 2023). Also, employing local indigenous knowledge for finding solutions highly influences the localization of SDGs in a location ('Localization of SustainablenDevelopment Goals and Indigenous Knowledge', 2022).

The convergence of India's national development goals with the SDGs was put into action by identifying developmental indices for all states and union territories (*Localising SDGS: Early Lessons from India*, 2019). The indices illustrated a high degree of disparity amongst the states and union territories reiterating the importance of local pocket-based development initiatives. According to NITI Aayog, the localization of SDGs in India is an ongoing process occurring simultaneously in three phases. The first phase focuses on identifying institutions and assigning tasks to achieve the SDGs at the central, state, and district levels. The second phase emphasizes increasing awareness and encouraging advocacy for SDG implementation. Development of indicators for measuring progress like the SDG India Index and Dashboard, and National Indicator Framework (NIF) were initiated. In the third phase, the collaborations between line ministries, state governments, and local governments were emphasized to focus on location-based goal setting, policy and strategy frameworks, development of national indicators for monitoring SDG, and organizing proper implementation system. Fig.1 shows the framework of SDG implementation in India (*Localising SDGS: Early Lessons from India*, 2019; Sengupta and Sinha, 2022).

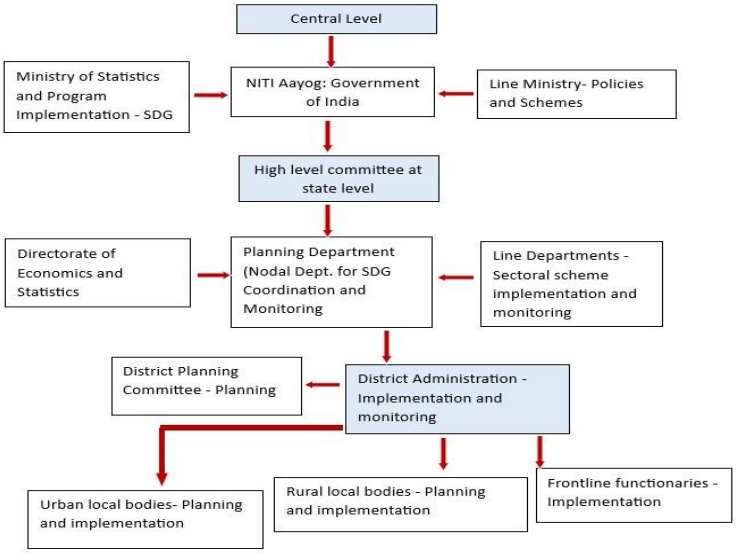

Figure 1. Framework of SDG implementation in India

Two important pathways for the localization of SDGs include strengthening the implementation of the goals and monitoring the progress. Gupta (2023) discusses five different frameworks that can be implemented for the localization of SDGs in the Indian context namely sector gap action plan framework, process re-engineering framework, inverted policy implementation flow framework, geographical prioritization framework, and private sector-driven SDG framework. However, the flow of financial resources and incentives to front-line workers are significant factors in ensuring the functioning of localization initiatives.

Kawakito Jiro Technique

Kawakita Jiro technique or KJ technique is a creative problem-solving approach, a qualitative data analysis tool, and a novel field research strategy (Scupin, 1997). It is a widely used socio-behavioral and attitudinal method for individual and group decision-making processes. Derived from Japanese ethnographic methods, the KJ technique is a participative qualitative research method that helps to get answers from a group of several people in the same peer group with a large subject area experience. As a collective participatory method, it is decentralized and non-hierarchical (Kunifuji, 2016). It also gives equal representation by allowing everyone to express their views regardless of their political and personal inclinations (Martin and Hanington, 2012). This method enables significant integration of miscellaneous data that cannot be compared to each other (Iba, Yoshikawa and Munakata, 2017).

KJ technique includes four sequential steps. Color-coded cards are usually used while implementing the KJ method. The first step is label-making which involves observation and expansive collection of data. Data collection can be through different methods like brainstorming, ideation, fieldwork, etc. The data points are individually written on color-coded cards and placed on a large sheet of paper. The subsequent step is termed label grouping. Here the different data points obtained are classified and grouped into categories. The grouping process needs to begin with smaller groups leading to a larger cluster signifying a bottom-up approach. The grouping is based on the affinity of meaning captured by the data labels rather than the resemblance of words. The process involves rigorous organization and reorganization of labels into different categories. Labels that do not belong to any specific category are called lone wolves and can be arranged during a higher level of organization. The next step is to name the group labels. Each category of problem space is given a name which is usually a summarized title of the concept imbibed in it. The title contains an abstraction of the concept or the problem category. The final step is to spatially arrange the different categories and trace the relationship between various categories. The different categories are thematically arranged, and problem space is visualized.

KJ method is an iterative process where the different labels are organized and reorganized to derive patterns and meaning out of it. This method enables a scientific approach to qualitative data giving realistic and objective conclusions. KJ technique has been extensively used as a planning and problem-solving tool in different domains like education, management, and social planning in Japanese society (Shimura, no date). It helps to bring together people thinking completely differently to handle questions that can receive strong opinions and tough debates. As a less explored non-Western paradigm, the KJ technique offers immense possibilities to capture the ground realities and make objective conclusions for decision-making.

The different facets of localization of SDGs including setting specific context-based goals and targets, implementation strategies, and measuring the progress and impact assessment need nuanced ground-level perspectives. The standpoints of various stakeholders bring rich data to enrich the decisionmaking process. This study aims to bring qualitative data on local development issues and contextinspired solutions through the collaborative work of local villagers as well as professionals to understand context-specific issues hindering achieving SDG goals in the remote Thar Desert region in India.

Methodology

Data Collection

A qualitative survey experiment was conducted with randomly sampled 73 participants to help strategize the localization of SDGs in Western districts of Rajasthan, India. These participants came from varied domains, including academia, central government, state government, village heads, local villagers, NGOs, and UN organizations. The participants were either located or working in these districts. These districts include Jodhpur, Jaisalmer, Jhunjhunu, Churu, Sirohi, Naguar, Sri Ganganagar, Bikaner, Barmer, Pali, and Hanumangarh. Fig 2 gives the map of the region included in this study.

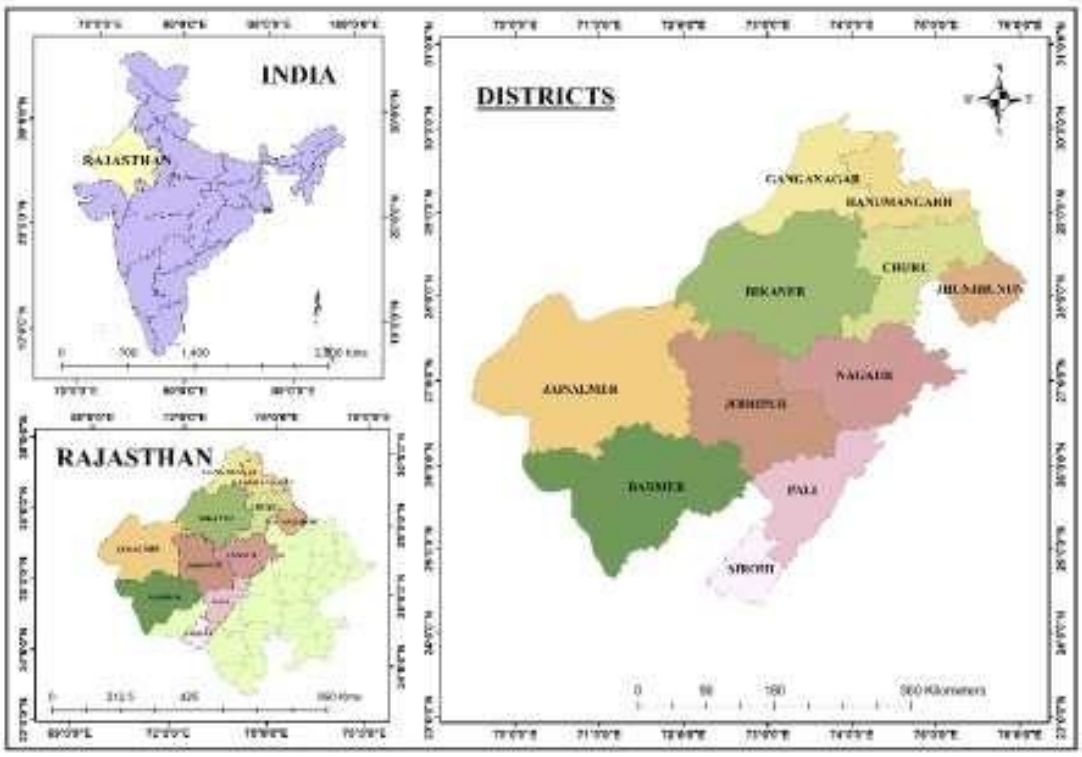

Figure 2. Map of the districts which were a part of the study

Each study participant was provided with two questions to think through the lens of their district or village to identify a local development problem, provide a local solution, and propose an approach to attaining the solution. The questions are as follows:

- Question 1: How Panchayat Development Planning process can be strengthened through tools for data analysis, costing methodology for planned activities, and prioritization of planned activities with an equity approach?
- Question 2: How can the capacities of panchayats be developed through innovative approaches for sustainable development?

Participants were given printed guidelines on the exercise in English and regional language along with three color-coded sticky notes to write their observations for individual questions. The pink note was given to note the problem, green for the solution, and yellow for the strategy to approach the solution. More than 10 volunteers including faculties, PhD scholars, and project staff were involved in communicating and assisting participants to work on this exercise. Besides, the participants were given almost a day to think through the problems to capture the nuances of ground-level problems in a granular manner and formulate their responses. However, the activity was conducted in a no-talking mode, and individual responses and observations were analyzed as per the rubrics of Kawakito Jiro approach.

Data Analysis Protocol

A large set of qualitative data was obtained from the responses of research participants. Each of the 73 participants answered the two distinct questions. Further, each of them provided three observations on effectively answering the two distinct questions with respect to their district of residence. The sticky notes were carefully analyzed manually, and similar data points based on their meaning were grouped into categories. All the sticky notes were analyzed carefully through multiple iterations to cluster them into categories. Each category was an abstract of a certain problem or solution in a particular district. This data was further quantified to draw inferences and similarities and differences between districts. Few observations were endemic to specific regions and were hence not included in these categories and were qualitatively analyzed. The data labels were mostly in Hindi along with a few English verbatims. All the Hindi data labels were carefully translated into English by capturing the essence of the participants' verbatims. This was followed by digitizing all the responses by entering them into a word document.

Results and Discussion

Based on the responses two significant themes include challenges in localization of SDGs and the feasible strategies to combat these challenges and work towards the 2030 Agenda.

Challenges on Localization of SDGs: Observations from below

Governance issues

Out of 73 participants, 47 (approximately 65%) participants discussed concerns regarding local governance. There are multi-dimensional issues regarding local governance discussed in detail. Graphs are plotted against the number of responses received from different districts. A significant issue is the lack of proper information and awareness on Gram Panchayat Development Plans (GPDP) including central and state government schemes on development among the villagers. Some 22% of the participants pointed out this pressing issue with it being more prevalent in Sri Ganganagar district. Graph 1 shows the graph plotted between different districts and the number of responses on the issue.

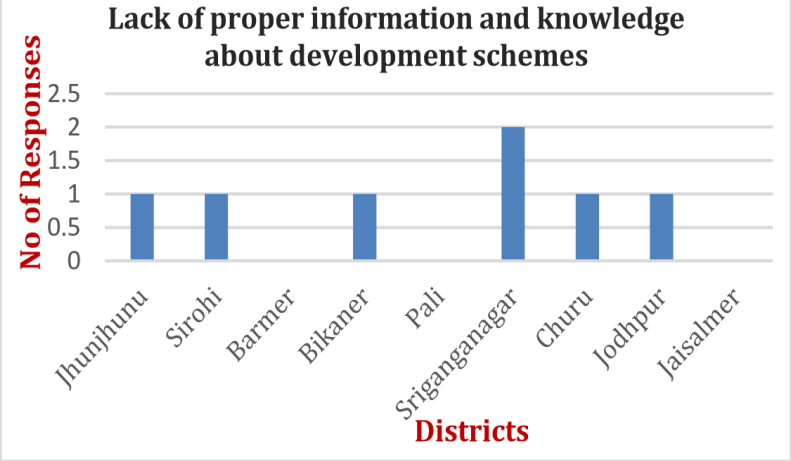

Figure 3. Lack of proper information on development schemes across districts

About 28% of the participants reiterated that illiteracy among the villagers is significantly affecting the governance process. Addressing illiteracy becomes important to achieve goal 4 on quality education and specifically target 4.1 on equitable primary education. Illiteracy is prevalent not just among the villagers but among elected panchayat representatives as well. Similarly, elective representatives are unaware of sustainable development goals and their importance and hence do not work towards them. Illiteracy indirectly prevents villagers from accessing their welfare schemes and from providing accurate data to measure progress. General illiteracy and digital illiteracy are more prevalent among women cohorts. Similarly, there is inertia towards acceptance and adoption of new technologies among the villagers. Graph 2 gives a glimpse of the districts where illiteracy is a shortcoming to achieving SDG goals.

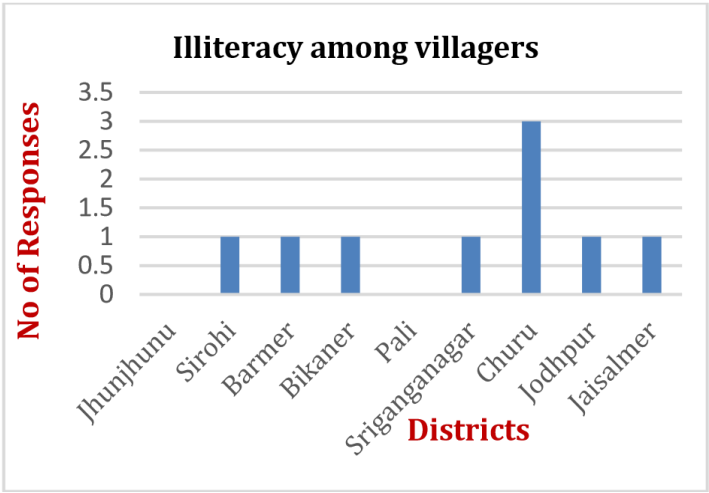

Figure 4. Illiteracy as a problem in the localization of SDGs in different districts

Target 16.7 of Goal 16 discusses the need for representative and participatory governance at all levels. The research shows a lacuna in local community participation constituting 18.75% of all the governance issues. This is more evident in the case of women who seldom participate in Gram Sabha meetings and

similar collectives happening at the village level. A participant verbatim is 'GPDP plans are designed and implemented by elected representatives without taking suggestions from villagers due to which village development is not happening properly'. According to observations provided by participants, similar systemic issues like corruption and lack of trust in the elected members also hinder community participation. Graph 3 gives the intensity of this issue in various districts of the experiment. This is more prominent in Jaisalmer district.

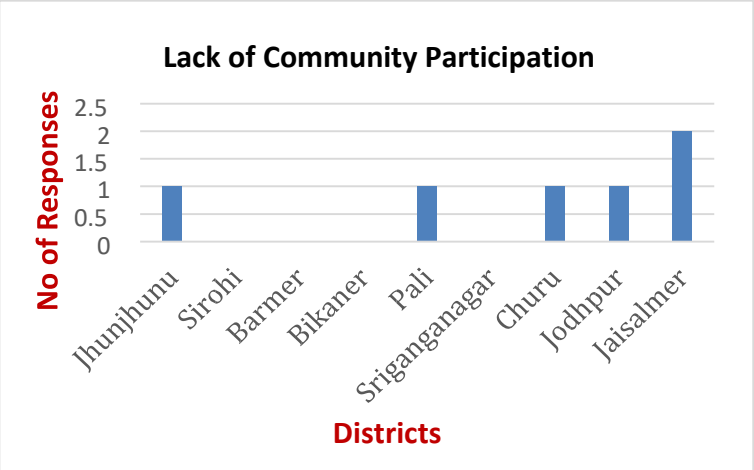

Figure 5. Lack of community participation in different districts

Effective functioning at any institutional level requires coordination and communication between various departments. The experiment has revealed the lack of collaboration between different departments at the village level as a serious concern in achieving SDGs. The lack of digital infrastructure and skilled human resources at the village Panchayat level is another issue. As per the observations by some respondents, one officer is given the responsibility of 2 villages leading to overwork among the officials and a time lag in the processes. Figure 6 represents the data obtained on the lack of coordination between the departments.

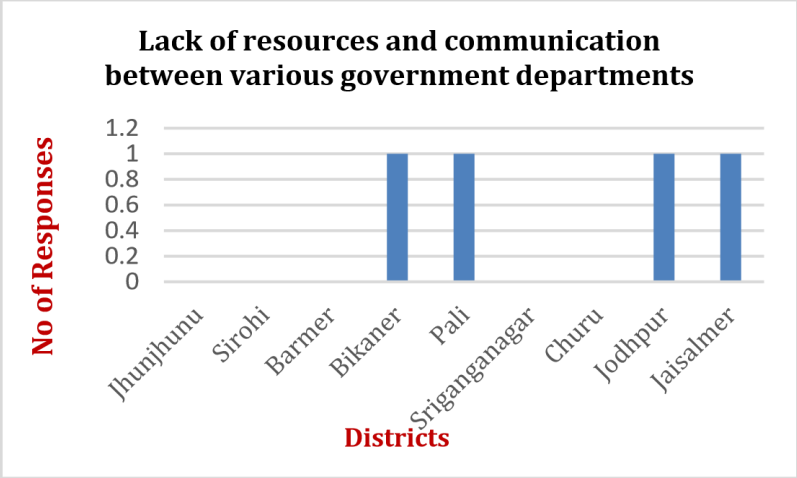

Figure 6. Lack of resources and communication between departments across districts

Lack of proper data on villages, improper beneficiary identification, and analysis of destitute and marginalized people is another challenge concerning local governance. It is prevalent in districts like Jaisalmer, Jodhpur, Barmer, and Pali. Figure 7 depicts the distribution of it across different districts.

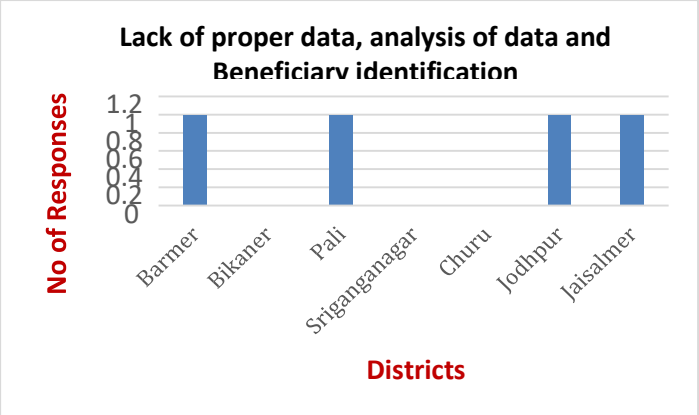

Figure 7. Lack of proper data across districts

Other issues include a lack of transparency in the governance process and a lack of social and financial audits in Jodhpur and Jaisalmer respectively. Proper financial auditing as per participants implies proper communication of financial decisions taken at the village level. Villagers feel that works undertaken at the Gram Panchayat are dependent on Sarpanch and Gram Sevak and the voices of the public are subdued. The officials do not give importance to collective decisions taken during general meetings and go by their individual choices. Funds allocated by the government are not efficiently utilized. Similarly, the nexus between the Sarpanch and local contractors at work affects the quality of work due to corruption. Jaisalmer district is one among the 112 districts on the Transformation of Aspirational District Programme where special emphasis is given to addressing intra-regional disparities on SDG goals. Addressing ground-level issues on transparency and financial auditing is essential to achieve targets 16.5, 16.6, and 16.7 which deal with reducing corruption, ensuring transparency, and inclusive and participatory decision-making. Figure 8 gives a comprehensive understanding of various local governance issues in the study region.

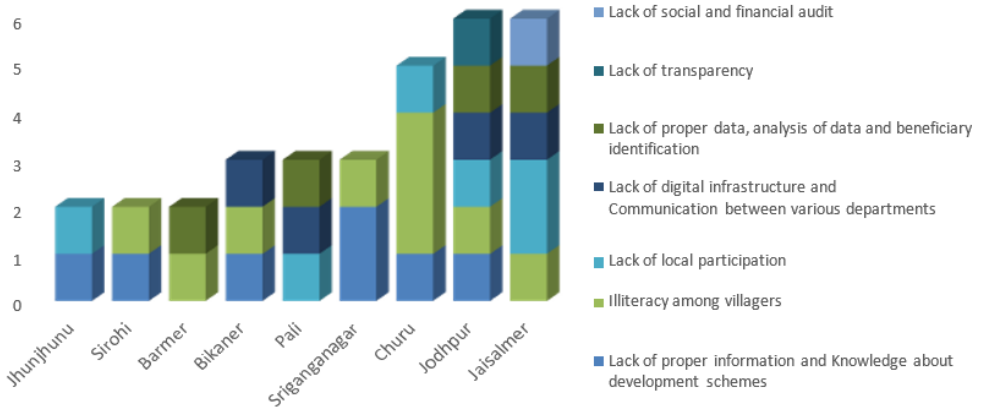

Figure 8. Compilation of governance issues

Issues concerning village data

Data-driven policymaking is an effective strategy as it enables to making of decisions tailored to specific needs and contexts thereby leading to efficient resource utilization. Data becomes a crucial component in monitoring progress and impact assessment as well. The participants discussed different concerns regarding village data. There is a lack of demographic and geospatial data on the village. The unavailability of village data online is also a concern. Limited digital infrastructure and digital devices at the village Panchayat level also contribute to the lack of real-time data. Also, few of the respondents communicated a link between the illiteracy of the villagers leading to their reluctance to reveal data. Improper data management and non-availability of data tracking and feedback options are determinant to assess the progress of the schemes. According to respondents, proper data analysis is required to find the actual need and target group to plan work accordingly. Figure 9 gives the different vertices of data issues.

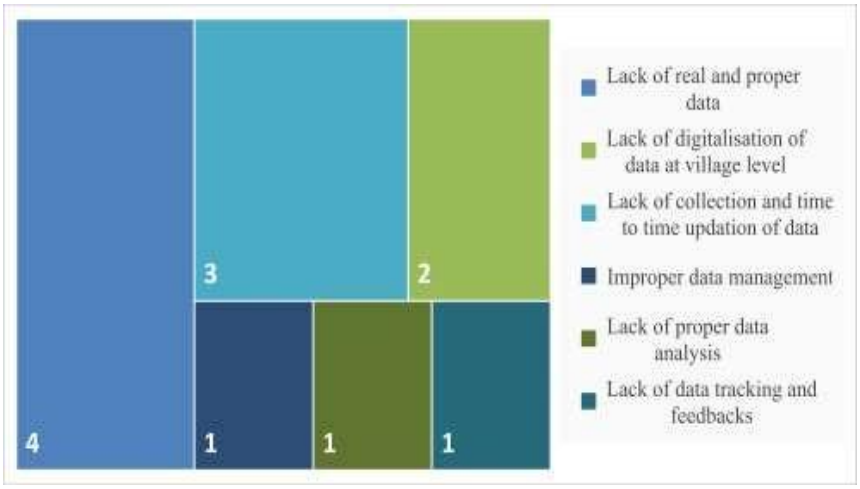

Figure 9: Issues concerning village data

Gender inequalities

Issues affecting targets of goal 5 on gender equality were revealed in the study. Illiteracy among women and inequalities in access to education are prevalent across the districts being studied. Higher education is often restricted to girls, and they are forced into early marriages. This needs to be addressed to achieve targets 5.1 and 5.3 on ending all kinds of discrimination against women and curbing early and forced marriages respectively. Lack of a safe public environment for women is also a concern that hinders their mobility and confines them to domestic spaces. Target 5.2 focuses on eliminating violence against women in public as well as private spheres which needs to be prioritised in these regions. Besides, a pressing concern is the lack of women's participation in local governance and decision-making processes. A few suggestions to resolve this include creating separate Mahila Sabha meetings to integrate them into Panchayat functioning and also provide a platform for discussing women-specific problems. Another suggestion is to motivate women to participate in Gram Sabha through RAJIVIKA or AJEEVIKA self-help groups and as ASHA (Accredited Social Health Activist) workers. Digital illiteracy, and lack of awareness of

health and menstrual hygiene, are also concerns that need to be addressed. Figure 10 depicts various women-centric issues.

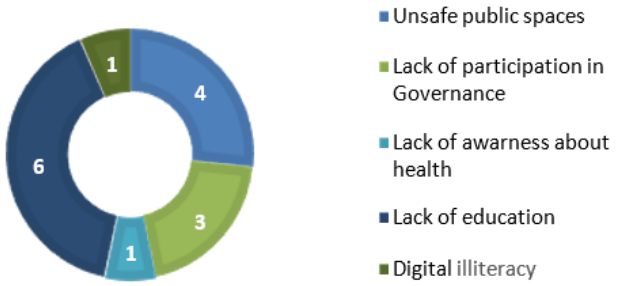

Figure 10. Women centric issues

Region-specific issues

Few issues were endemic to certain districts. Due to the location of these districts in the desert region, management of water resources is important. Sri Ganganagar district grapples with wastage and improper management of water resources. Similar is the case of Jodhpur where water pollution of Jojari river is affecting the animals and livestock population as suggested in earlier researches (Himanchal *et al.,* 2021; Meena, 2022). Jhunjhunu district faces issues in the proper harvesting of rainwater as well as issues in solid waste management. Targets 6.1, 6.3, 6.5, and 6.6 on ensuring the availability of water for all, reducing water pollution, integrated management of water resources, and restoration of natural water sources need to be prioritized in these regions. Drug addiction among youth is common in certain pockets of the Jodhpur district also needs attention.

Possible Strategies for Localization of SDGs

Three key areas to create a ground-level impact on local developmental policies included employing effective information dissemination strategies, upskilling communities, generating employment opportunities, and creating a strong collaborative institutional ecosystem by integrating different stakeholders.

Strategies for information dissemination

Ensuring the dissemination of proper and accurate information to all the villagers was an inevitable requirement in these locations. Increasing awareness about GPDP plans and other development schemes and creating transparency are important steps towards good governance. Thirty-eight percent of the participants emphasized the need to focus on information dissemination and 53% of them emphasized the need for bringing digital interventions. Developing and deploying a mobile phone application in regional languages with a simple user interface would be one such method. Contacts of all primary stakeholders need to be made available in the app enabling villagers to reach out. Forming an active community of villagers using a mobile application or WhatsApp group for villagers to help each other is suggested. Utilizing the communication possibilities of social media by creating social media pages

catering to specific villages is another strategy. Websites on important aspects like organic farming, water management, and healthy and nutritional lifestyle need to be created in regional language and shared with villagers. Language becomes an important parameter for effective communication and hence priority should be given to regional languages. Organizing training and workshops by experts is also preferred by 42% of study participants. Figure 11 is a representation of the responses received.

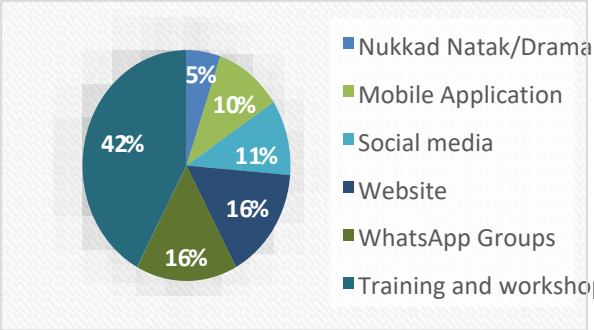

Figure 11. Strategies for Information Dissemination

Employment generation

Creating livelihood opportunities and modifying existing livelihood strategies stands as a viable solution to increasing the overall quality of life of the villagers. This aligns with target 10.1 on working to increase the income of the bottom 40%. This includes investing in upskilling the communities as well as creating education and skill development centers at the village level. With many artisan communities in these regions increasing village market connectivity and enhancing handicraft business possibilities through online platforms is required. Teaching primary data analysis and similar technical courses to children in village will help them fetch industry jobs. Technical institutions like Kaushal Vikas Kendra need to be created to provide training. Girls in the village with 12th-standard education can be given training in e-governance so that they can contribute to the workforce. These initiatives will contribute to achieving targets 4.3 and 4.4 on ensuring vocational education and skills for employment. Imparting innovations and sustainable technologies to increase agriculture yield is also important. Figure 12 shows the different suggestions to generate employment.

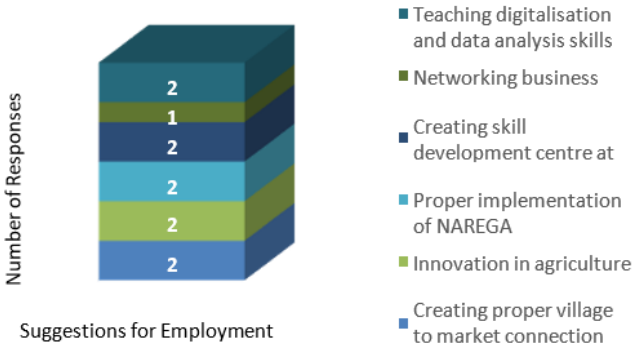

Figure 12. Employment Generation Strategies

Institutional Interventions

Multistakeholder participation has been emphasized to achieve the localization of SDGs aligning with Goal 17. Integration and collaboration between central and state government schemes might be beneficial for the village communities. Of the total, 41% of the participants asserted that government interventions with different schemes like the Unnat Bharat Abhiyan (UBA) scheme of the Government of India (Ministry of Education) need to be encouraged and expanded. Another inevitable intervention is to formulate proper rubrics to quantify development indicators as per the location. This needs to be based on surveys by different organizations like the Indian Council of Social Science Research, UBARCI (Regional Coordinating Institute), government agencies, etc. Various stakeholders should be mandatorily invited to develop Gram Vikas Yojana for villagers. Rural internships where college-going students are assigned to work in a village context for limited periods could also contribute to village development. Bringing NGOs and SHGs to work on par with the village development schemes is the next alternative. Figure 13 provides an overview of the suggestions for multistakeholder collaboration.

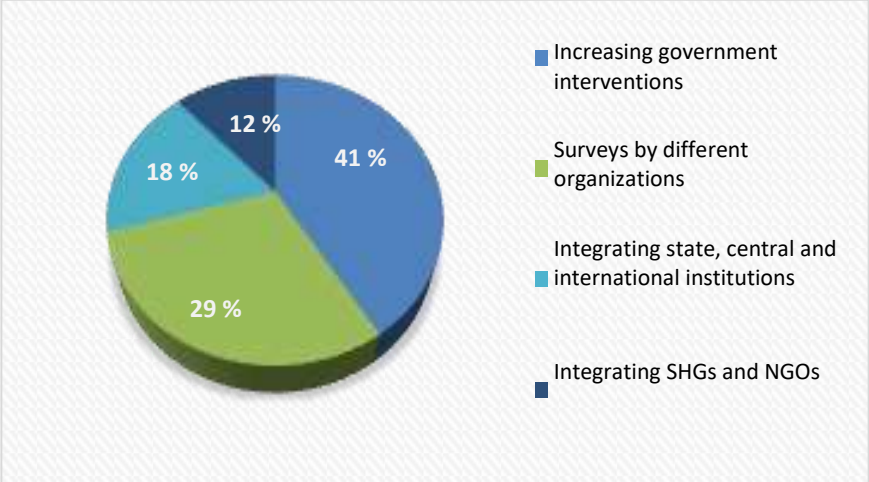

Figure 13: Institutional Interventions

Conclusion

Discourses on SDGs as well as goal 17 discuss the importance of multistakeholder partnerships in achieving the targets of the 2030 Agenda. A nuanced ground-level perspective from multiple stakeholders including the local communities brings a wealth of data to guide goal setting and impact assessment. This qualitative survey experiment was an initial step in this direction to bring various stakeholders to help design strategies and set priorities for achieving SDG goals in the remote Thar Desert region of Rajasthan, India. The region grapples with multiple local governance issues, structural inequalities due to caste and gender differentials, and a lack of proper digitalization. Lack of proper information and awareness on Gram Panchayat Development Plans (GPDP) and other government interventions for local development needs intervention. The lack of organized and updated village demographic and geospatial data and its unavailability to identify actual beneficiaries of the development schemes adversely affect the region. The community also felt disinterested in participating in local governance due to differences in political

groups, differences amongst caste groups, corruption, and experiences of their voice not being heard and considered in the decision-making process. Illiteracy among the villagers, elected representatives and panchayat level office bearers curb the evolution of much-required policy decisions from Panchayat sub-committees. The lack of human resources at the village level who are skilled to deliver developmental action is also a concern. Besides, the lack of livelihood opportunities, and educational infrastructure was a major observation in the different districts of Western Rajasthan. Similarly, there is limited digital infrastructure availability at the village level further accentuating the digital inequalities faced by these already spatially marginalized locations.

A multivariate analysis was inevitable to discuss and confirm the correlations between different governance issues observed above in Figure 7 and Figure 8. The line plot of eigenvalues while studying principal components in the study is provided in Figure 13. From this plot, the principal components namely 'Lack of proper information and knowledge about development schemes', 'Illiteracy among villagers', and 'Lack of community participation' have an Eigenvalue of more than 1. Therefore, these three parameters are enough to explain about 80% of the influence on the results of the study here.

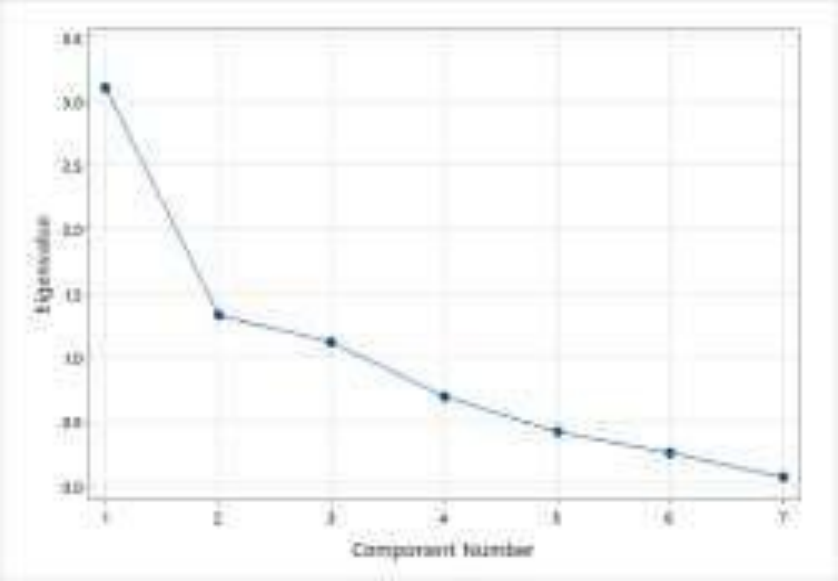

Figure 14. Scree Plot for assessing the most important variables of this study

It is found that 'lack of local participation' diverges from the variable of 'lack of proper information and knowledge about development schemes'. This means that even though local participation occurs, the knowledge of the developmental schemes of the governments is not discussed in those gatherings. Similarly, from Figure 15, the 'lack of digital infrastructure' at the village level is found to be positively correlated to the 'lack of proper data, analysis and beneficiary identification'. This also supports the first component of less knowledge amongst village residents on government development schemes due to less effective communication technology provisioning, probably due to the dilapidated digital infrastructure in the villages of Rajasthan. Figure 15also supports the fact that non-penetration of development schemes in the villages is also the reason for low literacy in these locations, especially among women in these communities.

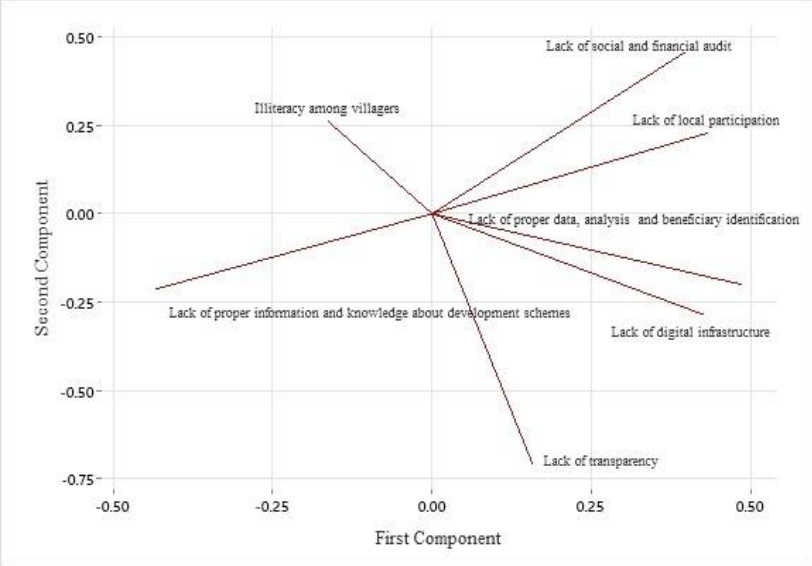

Figure 15. The Loading Plot of different parameters in governance

Further women-centric struggles include a lack of safe public spaces and infrastructure, unavailability of water resources, early marriages, and illiteracy including digital illiteracy. Low job availabilities within the village or block level for the level of education, as well as local government interventions to understand these concerns from the perspective of villagers, need interventions. Further Graph 13 confirms that less transparency in administrative processes limits the dissemination of information on development schemes which may indirectly hinder the educational aspirations of the individuals in the society.

Limitations and further scope: There were an unequal representation of research participants from different districts which may have influenced the data. As a qualitative research strategy was employed it is impossible to eliminate minor chances of biases. However, the study was able to capture the granularities of groundlevel issues to guide the localization of SDGs. A field study with focus group discussion and similar experiments with the villagers and the Panchayat level representatives can further guide the goal-setting process. The implications of this bottom-up qualitative study with multiple stakeholders with first-hand experience in these local regions also unveil a feasible methodology to set the direction for the localization of SDGs at the village level in low- and middle-income countries.

Acknowledgement

We sincerely thank IIT Jodhpur, UNICEF India, ARAVALI and UBA-RCI for giving us a platform to conduct this experiment. Our heartfelt gratitude to UNICEF Rajasthan for providing us with the financial resources to conduct this experiment. We are also grateful to all the research participants for their efforts to contribute to this study and enrich the data collection process. Our special thanks to all PhD scholars and STI project staff for all the logistical support throughout the experiment. Special thanks to Prathamesh, Himanchal, Sunil Duhan, Meraj Ahmed, Ram Singh, Nikita A. K, Nikhil Suresh, and Dinesh for helping with Hindi translations, and other detailing during the experiments.

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Posters

Submission ID: 82

The Current State of Models Covering the Sustainable Development Goals and Planetary Boundaries

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Abstract

The sustainable development goals (SDGs), adopted by the United Nations, are widely used as a framework to transform our world towards sustainability. However, countries are not on track to achieve them by 2030. The SDGs are important in themselves, but achieving them might be insufficient for long-term sustainability. To achieve long-term sustainability, we need to stay within the planetary boundaries (PBs) and avoid dangerous environmental tipping points. Therefore, we need to know the consequences of underachieving the SDGs on the PBs. So far, there are no models that include all SDGs and PBs. Such holistic models are necessary for the scenario analysis of sustainable development. Therefore, we have the following questions to answer. How are the SDGs linked to the PBs? What is the state of art of models including SDGs and/or PBs?

We will answer these questions by doing a systematic literature review on the current state of system models, covering at least some of the SDGs and PBs. In this review, we search for papers that include terms on SDGs or PBs and terms on modelling or simulating in two databases: Web of Science and Scopus. For example, for Web of Science we use the following search: *Sustainab* AND (SDG* OR "sustainable development goal*" OR "planetary boundar*") NEAR/10 (~model* OR ~simulat*).* For this search, Web of Science provides a list of 813 articles. We do a similar search in Scopus. Next, we select the relevant papers from this list by reading the titles and Abstracts.

With the outcome of the systematic literature review, we write a report on the relations between SDGs and PBs and we make a clear overview of the current state of models about sustainable development which are used for simulating SDGs and/or PBs. Also, we tell which models are most promising to cover all SDGs and PBs. We expect to find an integrated assessment model to be the most suited candidate to expand. We expect that there is already a wide range of models relating SDGs to planetary boundaries covering climate change, but that the other PBs are related to SDGs less.

In this systematic literature review, all SDGs are included. The research contributes to the conference as we investigate the relation between SDGs and PBs. This result is useful for the relation between the achievement of the SDGs by 2030 and sustainability afterwards.

1c. Assessing Sustainability

Abstracts

Submission ID: 4

Mapping SDGs Priorities: Localising SDGs, Analysing Interactions, and Crafting Sustainability Solutions

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Abstract

The United Nations 2030 Agenda offers a comprehensive framework for global sustainability through its Sustainable Development Goals (SDGs), encompassing a wide array of societal, economic, and environmental aspirations. Yet, the successful localisation and implementation of these goals demand an intricate understanding of their multifaceted interactions, recognising both synergies and trade-offs that manifest at local levels. In our in-depth study situated within the Goulburn-Murray region of Victoria, Australia, we embarked on a rigorous exploration to align global SDGs with local imperatives. We conducted a detailed analysis to identify the most important SDGs and their targets that are relevant to the specific challenges and opportunities in the region. Through meticulous research, we pinpointed five overarching SDGs of heightened relevance: clean water and sanitation (SDG 6), agricultural activities (SDG 2), economic growth (SDG 8), climate action (SDG 13), and life on land (SDG 15). Within this localised framework, our investigation revealed a complex tapestry of 307 potential interactions among these prioritised SDGs and their associated 45 targets. Fascinatingly, a significant 41% of these interactions exhibited synergistic relationships, amplifying the potential benefits when pursuing multiple goals simultaneously. However, a discerning 6% revealed trade-offs, signalling areas where concerted efforts might inadvertently hinder progress in other domains. Notably, our findings underscored the intricate balance required, particularly emphasising the repercussions of unsustainable agricultural practices on crucial facets like water resources, environmental integrity, and the foundation of sustainable economic growth. Moreover, the Goulburn-Murray region isn't immune to global uncertainties and evolving dynamics. Factors such as climate change, fluctuating agricultural commodity markets, evolving international trade landscapes, and progressive water policy reforms introduce layers of complexity for agriculture and the local economy. These uncertainties could potentially thwart the region's strides toward SDG attainment, necessitating adaptive strategies and robust policy frameworks. Drawing from our comprehensive analysis, we accentuated actionable policy solutions designed to harness synergies effectively while mitigating identified trade-offs. For instance, initiatives targeting SDG 13 (climate action) and SDG 15 (life on land) showcased predominantly synergistic co-benefits, presenting avenues for integrated planning and execution. Conversely, our insights illuminated areas of caution, particularly around SDG 2 (agricultural activities) and SDG 8 (economic growth), where proactive measures are imperative to circumvent adverse outcomes stemming from unsustainable agricultural practices. In conclusion, our research underscores the paramount importance of holistic, context-specific analyses when navigating the intricate landscape of SDG localisation. By unravelling the intricate web of SDG interactions within the Goulburn-Murray region, we offer beneficial insights for policymakers, stakeholders, and communities. While our findings are deeply rooted in this specific context, the methodological approach we've pioneered holds promise for broader applicability. It furnishes stakeholders across diverse locales with a replicable blueprint for dissecting SDG interactions, fostering policy coherence, and advancing sustainable development agendas tailored to unique regional nuances.

Submission ID: 32

Integrating Stakeholder Perspectives in Assessing Sustainability of Agriculture Water Management Practices

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Abstract

One of the biggest challenges in agriculture is meeting the growing demand for food while managing limited water resources. This issue exists globally and at the farm level, driven by limited water availability and declining water quality, fragmented governance structures, limited stakeholder collaboration, cultural values, and diverse economic conditions. Different solutions have been developed to encourage a shift towards sustainable land and water management, including the appropriate construction policies, user- and environment-friendly designs, and smart and innovative water technologies. Among these, smart technologies are increasingly used for efficient monitoring, optimization, and forecasting, supporting environmental sustainability. They've also made jobs more attractive (economic sustainability) and boosted digital literacy (social sustainability) However, there are concerns that the innovative technologies are technically complicated, economically expensive, and limited to certain groups of farmers and may not consider passive stakeholders. Hence, it is crucial to analyze these technologies in terms of sustainability, innovation, operational capacity, customer-centricity, and their impact on the transformation of agricultural activities both now and in the future. A rapid ethnographic field visit and semi-structured key informant interview were conducted with different groups of stakeholders from Canale Emiliano Romagnolo (CER) in Italy and Seeland, Switzerland. The aim was to study the status of current water management practices in farms and obtain the stakeholder's perspective regarding the sustainability of innovative water management technologies like 'remote sensing pipelines and integrated physically based terrestrial system models'. Our study found that current water management practices were 'environmentally' sustainable with technically advanced water management systems, but there is a need to reconsider social sustainability by creating room for involvement and collaboration of diverse groups of stakeholders and economic sustainability by enhancing market mechanisms. We also observed positive attitudes toward using innovative technology; however, concerns were raised about its use in terms of technical complexity, reliability, and prices. Our study highlights the importance of creating management systems that enable decision-makers to engage with a diverse group of stakeholders to achieve the sustainable transformation of agricultural water management activities. Such systems can streamline policy formulation and implementation, considering the concerns of stakeholders at the farm level. The research primarily focuses on the sustainability of water management in agriculture, with an emphasis on innovative technologies for efficient water management and incorporating input from stakeholders. This research primarily addresses SDG 6 - Clean Water and Sanitation (Target 6.3, 6.4, and 6. b), as well as SDG 2-Zero Hunger (Target 2.3 and 2.4). The impact of this research extends beyond agriculture to food, water availability, and climate change, making it relevant to the conference's theme of "…sustainable livelihood." Additionally, the research addresses the concerns of "... stakeholders to assess and report sustainability issues," aligning with the theme of" Sustainability and Science".

Keywords: *Sustainability, Water policy, Innovative solutions, Stakeholders, Climate change*

Submission ID: 208

Discourse Workshop on Proposed Ground Rules For Full Cost Accounting Methods For Product Sustainability Assessment: How Can We Ensure Valid Estimation Of Hidden Costs Of Products?

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Abstract

Many environmental and social impacts in product's value chains are currently unaccounted for in the price of products. Several methods exist to calculate both the pressures of such impacts, as well as their monetization. These approaches are named Trueprice, TruCosts, Sustainable Value, True Value, Oiconomy Pricing, hidden price etc. In the context of live cycle assessment (LCA), expressing environmental and social impacts in monetary terms allows for aggregation and easier communication. Many methods for monetization exist, with fundamental differences in their underlying monetization approach, accuracy, availability and application. Several scientific and consultancy initiatives have contributed to this development by introducing monetization methods that also use different methodologies. In a recently published article, we reflect on the differences between such existing methods. The scope of these methods is very diverse, while underlying theoretical and methodological choices are not always transparent. This creastes risks of greenwashing. Based on our review, we have proposed four exploratory ground rules for full cost accounting methods. These are:

1. Be consistent, explicit and comprehensive in the selection and framing of the sustainability domains and the impact pathways for each.
2. Be consistent and explicit in justifying the choice for monetary valuation methods and respect the time dimension distinction (costs related to either before or after the activity of production)
3. Be consistent and explicit in justifying the inclusion of positive externalities and refrain from summing negative externalities and positive externalities.
4. Be fully transparent about which monetary valuation coefficients and data sources are used.

After publishing the article, we have started an online discourse with scholars in this field. We will share the preliminary results and continue this discourse during the workshop in Nepal with the attendants. The results of this discourse will be published after the conference.

- The full article is published at: https://doi.org/10.1016/j.indic.2023.100275
- You are invited to join the online discourse at: https://www.linkedin.com/groups/12862281/
- ISDRS member have been invited to this discourse in ISDRS Q3 Newsletter 2023

Submission ID: 218

Invitation to the Open Science Agenda on Full Cost Accounting with the Oiconomy Pricing Approach

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Abstract

The recently implemented European legislation on sustainability and value chain transparency (CSRD, CDD) leaves companies with the need for monetization of environmental, social and economic impacts of their processes and products. Several scientific and consultancy initiatives have responded to this need by developing monetization methods. These methodological approaches aimed at determining the 'hidden price' have names like Trueprice, TruCosts, Sustainable Value, True Value, Oiconomy Pricing, etc. A recent review showed fundamental differences in their underlying monetization approach, accuracy, availability and application (Roos Lindgreen and Vermeulen 2023).

In this paper, we focus on recent experiences with piloting Oiconomy Pricing. The methodology is aiming at a valid, fair, inclusive, and up-to-date representation of the real price of products. It addresses all sustainability aspects (Planet, People and Prosperity) and visualizes these aspects for the entire value chain of products or services. It assesses these aspects based on the actual actions of the parties in the value chain and it translates the data on the actual actions of these parties in the value chain into the costs necessary for the prevention of the negative consequences for nature and society, as described in the United Nation's Sustainable Development Goals. Eight different case studies have been conducted with the pilot version of the method. In these cases, end-producers of various types of products and their suppliers, together with academic researchers applied the Oiconomy Pricing method at the company level. Based on this, we analyse the need for further improvement and implementation of this form of full-cost accounting and opportunities for value-chain collaboration.

Based on these experiences, the Oiconomy Pricing Foundation has elaborated an Open Science agenda for further improvement of this methodology. During the presentation of this paper, we will discuss how scholars around the globe can contribute to the further development and application of the Oiconomy pricing approach.

Submission ID: 219

Just Transition and Stakeholder Perspective: A Focus on South African Employees within Coal Industry

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Abstract

As global efforts to mitigate climate change intensify, the coal industry faces unprecedented challenges, necessitating a transition towards sustainable alternatives. Despite its significant contribution to greenhouse gas (GHG) emissions, coal has contributed to job creation for many people across the globe. Meanwhile the South African coal sector transitions to a net-zero carbon economy, massive effects on jobs are anticipated. The alternative jobs from the green economy may provide lower wages and lower levels of responsibility, resulting in employees losing their professional pride, socioeconomic status, and personal identity. Taking into consideration that, if the implementation process of the coal phase-out is not carefully executed through robust and context-based policies, programmes, and plans, it could result in increased social and economic commotions. Which is why this study is assessing the readiness and preparedness of important stakeholders (coal sector employees) in South Africa. This was achieved through investigating their awareness of the concept of just transition, understanding the perceived impacts, and response mechanism in place for a smooth and equitable transition. Employing a non-parametric quantitative approach, data was collected through surveys targeted to key employees within the coal value chain. Such included coal company employees, transport employees and major coal consumer's employees. The preliminary findings reveal that just over a half of total respondents (53%) are aware of just transition, however with very little level of familiarity with the concept. Suggesting that they have heard of just transition, yet with little understanding of its complexities. Nevertheless, most respondents indicated that instead of leaving their jobs in mining coal they would rather transition to mining other minerals. Notably, very few respondents (6%) indicated that they have been exposed to reskilling and upskilling programs. According to employees among many identified impacts job losses were the most prevalent impact of transition, followed by economic restructuring, increased poverty, and inequality, respectively. The study therefore recommends the following: 1) promoting and supporting upskilling and reskilling programs tailored to the needs of the affected. 2) More research on comprehensive impact assessment associated with transition that includes, income stability, potential changes in living standards, and migration issues. 3) More targeted awareness programs and training sessions to educate employees about the concept of just transition, its benefits, and challenges.

Keywords*: Just transition, awareness, coal employees, impacts*

Submission ID: 278

Methodological Approaches for Developing Inter-Scale Participatory Sustainability Indicator Systems

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Abstract

Sustainability indicator systems (SIS) are playing a central role in assessing and reporting sustainability performance at different levels. They are a key topic of discussion in both academic and practical circles, as their development presents a significant challenge. Given the multifaceted nature of sustainability and the complexity of the SIS, methodologies for its measurement are crucial. In this regard, diverse approaches and methodologies are being used to integrate the various dimensions of sustainability within a framework built upon a set of indicators.

This study aims to evaluate the development of inter-scale participatory sustainability indicator systems (SIS) through a literature review. This includes analyzing the methodologies employed and identifying areas for future research. Inter-scale participatory SIS offer a more comprehensive picture of sustainability, empower stakeholders because their participation is crucial for defining SIS, reflecting a variety of needs and priorities and it considers different levels, like families, communities, cities, regions and countries allowing not just the understanding of the interconnection between scales but also fostering collaboration for better sustainability outcomes.

The emphasis here lies on identifying innovative methodologies that incorporate participatory processes within SIS development. The preliminary results show that inter-scale participatory SIS are a relatively under-addressed area of research. Furthermore, the inter-scale dimension often only considers two levels, such as, regional and local or national and regional.

Participatory methodologies tend to follow a similar pattern: starting with existing indicators (e.G, UN Sustainable Development Goals) and then engaging stakeholders through surveys, online platforms, workshops, focus groups, or expert panels to refine the indicators. Future research will face some challenges:

- Develop innovative methodologies that move beyond existing indicator sets and incorporate novel data sources;
- Explore the relationships between different levels to improve the effectiveness of collaborative sustainability efforts;
- Ensure fair representation of stakeholders across scales;
- Build capacity for meaningful participation by developing skills and knowledge among stakeholders;
- Address the challenges of data collection and normalization, which require expertise and time.

Overall, this is a promising area of research. The methodological approaches used in SIS based on participatory approaches are fundamental for an appropriate development of these systems and have the potential to significantly improve sustainability assessment and action.

Submission ID: 303

Global Actions towards Climate Action Goal (SDG 13): A Bibliometric Review

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Abstract

Climate change is a pressing challenge the world is facing currently (Glaser, J. *et al.*, 2016). It is rising, and mitigation efforts at all scales are not sufficient (Creutzig *et al.*, 2018; Grubb *et al.*, 2022). Therefore, climate action is imperative in tackling the urgent and unavoidable challenges posed by climate change on the environment, economy, and society and securing a sustainable future for our planet and future generations (Markowitz & Shariff, 2012). This study aims to study the global climate action goal of SDGs, i.e., SDG 13 by doing a bibliometric review of the scientific research documents produced on SDG 13. This study uses the pre-generated query string related to SDG 13 to fetch bibliographic data from Scopus. Pre-generated query strings for all the SDGs are provided by Scopus itself (Maxime *et al.*, 2023). VOSviewer and Biblioshiny (R-Studio) software tools are used for data analysis. These tools are apt, user-friendly, and free from coding (Aria & Cuccurullo, 2017; Markscheffel & Schröter, 2021). This study uses performance analysis and relationship analysis techniques, which are very common in bibliometric studies. Performance analysis uses publication count, citation count, CiteScore, h-index, SJR, SNIP, NIR, QS ranking, and number of fundings as metrics. Bibliographic coupling, three-field plot, and keyword co-occurrence are used for productivity and relationship analysis of different research elements (e.g. journals, authors, affiliations, and countries) (Donthu *et al.*, 2021). This study presents an idea to researchers and policymakers about the current state of research related to SDG 13 (climate action) and about future research scope. Policymakers can get insights from this study for policymaking. Researchers can also take up similar bibliometric studies for other SDGs. Along with performance and relationship analysis, other enrichment techniques, such as exploratory factor analysis (EFA), hierarchical clustering, island algorithm, etc., can be used for similar kinds of studies (Donthu *et al.*, 2021). Artificial intelligence (AI) and machine learning (ML) can be used for more comprehensive results. Like other studies, this study, too, has limitations. Data and outcomes related to Scopus database are dynamic due to the continuous addition of research documents.

Keywords: *Climate change, Climate action, Bibliometric review, Pre-generated query, Bibliographic coupling, Keyword co-occurrences, Three-field plot.*

Full Papers

Submission ID: 56

Statistical Variability of LCA Results Using Regionalized and Representative Inventory Data: The Case of Olive Production in Italy

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Abstract

Life Cycle Assessment (LCA) is one of the most adopted methods for assessing the potential environmental impacts associated with the life cycle of agri-food products and related agricultural practices. Despite this, there is a common consensus among scholars on the need for site-specific Life Cycle Inventories (LCIs) that should be as much as possible representative of the investigated agri-food system. In this regard, the Research Projects of National Interest (PRIN) 2017 "Promoting Agri-Food Sustainability: Development of an Italian LCI Database of Agri-Food Products (ILCIDAF)" aimed at developing Italian regionalized databases including representative LCIs for four agri-food products, to be used in LCA studies, i.e., cereal and pasta, wine, citrus and olive oil. The aim of this study is to analyse the statistical variability, among 19 Italian regions, in terms of Life Cycle Impact Assessment (LCIA) results that may occur using inventories that are representative of each region. Results show high variability among the 19 Italian regions in all the impact categories investigated. In particular, the coefficient of variability ranges from 43.87% in climate change to 49.75% in eutrophication (freshwater). The highest variability, in all the analysed impact categories, emerges for ferilizers and diesel production, and direct emission to air.

Introduction

Agri-food productions are responsible for high environmental impacts, accounting, globally, for onethird of anthropogenic greenhouse gas emissions, 70% of water use and 90% of deforestation. Agricultural activities also contribute to 70% and 50% of terrestrial and freshwater biodiversity loss as well as they cause land degradation (UNCCD, 2022). Furthermore, the World population is expected to reach 8.6 billion people in 2032, causing a yearly growing demand for food products for about 1.3% (OECD and FAO, 2023). This may result in further environmental issues mainly connected to agricultural practices implemented for food production.

Life Cycle Assessment (LCA) is considered the most suitable and adopted method for assessing the environmental impacts related to agricultural processes and food production (Notarnicola *et al.*, 2017). Indeed, LCA is a standardized method that allows the assessment of the potential environmental impacts associated with a process, product, or service throughout its whole life cycle, from raw material extraction and processing, through manufacturing, transport, use and end-of-life (Guinée, 2002). According to the ISO 14040:2006 standard (ISO, 2006), the LCA framework is characterized by four iterative phases, i.e., 1) Goal and scope definition; 2) Inventory analysis; 3) Impact assessment; and 4) Interpretation. With specific regard to the Life Cycle Inventory (LCI), various scholars highlighted the need to collect and use data that are as much as possible representative of the investigated system (Notarnicola *et al.* 2022; Frischknecht *et al.*, 2019). Indeed, the use of site-specific data would improve the representativeness and reliability of the LCA outcomes. This is particularly true for the agri-food sector, in which agricultural activities and food

processing may strongly vary among different geographical contexts. Indeed, technological, biological, and environmental factors characterise each agri-food system and the related production processes (Liliane and Charles, 2020), thus requiring sitespecific and representative data for LCA practitioners. In this context, the Research Projects of National Interest (PRIN) 2017 "Promoting Agri-Food Sustainability: Development of an Italian LCI Database of Agri-Food Products (ILCIDAF)" had the scope of developing a database, to be used in LCA studies, including LCIs datasets representative and regionalized for the Italian context, and related to four agrifood products, i.e., cereal and pasta, wine, citrus and olive oil. The ILCIDAF database (ILCIDAF, 2024), which includes 924 datasets, has been developed using both primary sources directly collected through questionnaires and direct interviews submitted to agri-food companies and secondary data obtained through statistical databases, agricultural handbooks and scientific literature related to the Italian context.

Starting from the ILCIDAF database, this study aims to assess the potential environmental impacts related to agricultural practices implemented for olive production among 19 Italian regions – i.e., Abruzzo (ABR), Apulia (APU), Basilicata (BAS), Calabria (CAL), Campania (CAM), Emilia Romagna(EMR), Friuli Venezia Giulia (FVG), Lazio (LAZ), Liguria (LIG), Lombardy (LOM), Marche (MAR), Molise (MOL), Piedmont (PIE), Sardinia (SAR), Sicily (SIC), Tuscany (TUS), Trentino Alto Adige (TAA), Umbria (UMB) and Veneto (VEN) – through the application of the LCA method. In particular, the scope is to investigate the statistical variability, among these regions, in terms of Life Cycle Impact Assessment (LCIA) and to point out the importance of using inventories that are representative of specific regional contexts.

Literature Review

Various commercial and non-commercial LCA databases are available for practitioners involved in the analysis of agri-food systems. Some of these databases are specifically related to the agri-food sector, such as Word Food LCA Database (WFLDB) (Nemecek *et al.*, 2019), Agribalyse (Koch & Salou, 2020) or Agri-footprint (Blonk Consultants, 2014), while others include data related to multiple sectors, such as Ecoinvent (Frischknecht *et al.*, 2005). In addition, despite some LCA databases being proposed in order to cover a specific national context (e.G, Agrybalise for France), most of them include multigeographical boundaries, from World to national level, but none focus on a regional context.

The article proposed by Mondello *et al.* (2022) highlighted that Ecoinvent is mostly used as a standalone database or in combination with other databases in studies in which the agri-food sector and, in particular, the olive oil supply chain, are evaluated through the LCA method. Indeed, LCA practitioners commonly require the use of secondary data through dedicated databases, when foreground data are not available. Despite Ecoinvent being considered one of the most well-known and exhaustive databases, including more than 20,000 datasets related to various materials, energy sources and processes (Ecoinvent, 2024), it may lack geographical representativeness for data related to agri-food systems. Indeed, with specific regard to olive oil production in Italy, Notarnicola *et al.* (2022) pointed out that only one dataset is focused on the agricultural processes (i.e., olive production) related to this supply chain, including 70 data among inputs and outputs, of which only 4 are specifically related to Italian boundaries. In this context, the use of LCI datasets that are non-representative nor regionalized for a specific geographical context may lead to biases and uncertainty in the results obtained through the LCIA phase in LCA studies focused on olive or olive oil production as well as on the agri-food sector in general. Thus, the study here proposed has the

scope of highlighting the need for inventory data that are able to capture the different factors affecting agricultural processes and related products among various geographical boundaries.

Methodology

In this section, the four methodological phases included in the LCA framework (ISO, 2006) are reported, describing its implementation in the investigated olive production systems in 19 Italian regions.

Goal and Scope Definition

The goal of this study is to assess the potential environmental impact related to olive production in 19 Italian regions. In particular, a hotspot analysis is performed in order to understand which inputs, outputs or processes are responsible for the highest environmental impacts among regions. Then, a statistical analysis is applied to LCIA results, to point out the grade of variability occurring between regions in terms of environmental impacts, depending on the use of representative and regionalised data. In addition, the statistical variability is also investigated by comparing the LCIA results obtained using the ILCIDAF datasets related to each region and the sole dataset included in Ecoinvent, to be considered as representative of the Italian average olive production. The functional unit (FU) selected for carrying out the analysis is represented by 1 kg of harvested olives. This FU is chosen according to the study of Notarnicola *et al.* (2017), by which mass-based FUs emerged as the most adopted among LCA studies related to the agri-food sector. System boundaries follow a cradle-to-distribution approach (figure 1), In particular, all the processes involved in olive production are included, specifically soil management, irrigation, fertilisation and pest control, pruning and harvesting. In addition, transport activities of inputs to the farm and olives to the olive mill, as well as waste treatment are also included. Cut-off criteria include the production of capital goods (i.e., machinery, equipment and infrastructures).

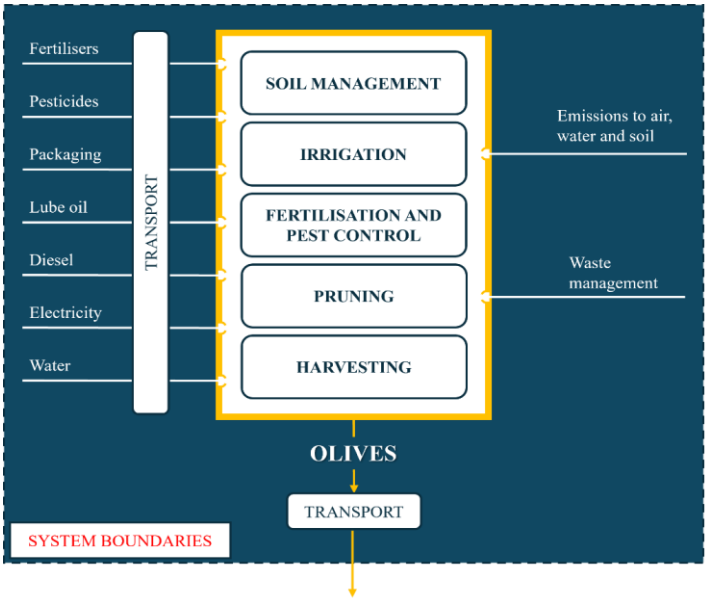

Figure 1. System boundaries of the investigated olive production system.

Inventory Analysis

To pursue the scope of this study, the LCI is built using data from the ILCIDAF database. In particular, data related to olive production in the 19 Italian regions are obtained using datasets developed from secondary sources that are specifically related to each geographical context. Indeed, data related to the average olive yields, to which all the inputs are normalised, are obtained through ISTAT (2021) considering the timeframe between 2015 and 2020. Data for fertilizers (nitrogen, phosphorus pentoxide, and potassium oxide) and pesticides (copper and Maconzeb) are gathered from the Guidelines for Integrated Production (GIP) available per each of the investigated regions (GIP, 2021). In addition, data related to irrigation processes (electricity and water) and machinery and equipment use (diesel and lubricating oil) as well as on packaging for chemicals are respectively collected by Ribaudo (2017) and Ecoinvent 3.9 database (Moreno Ruiz *et al.*, 2022). Regarding the outputs, secondary sources are also used for modelling waste management processes related to lubricating oil (CONOU, 2022), packaging (EC, 2021), and pruning Ribaudo (2017). Direct releases to air, water and soil are calculated using specific emission estimation models available in the international scientific literature (e.G, Notarnicola *et al.*, 2023; Zampori and Pant, 2019, etc.). Further information about data collection and calculation adopted for olive production in the ILCIDAF database are reported in Saija *et al*. (2024). Background data associated with the production of inputs and waste treatment processes are obtained using the Ecoinvent 3.8 database (Moreno Ruiz *et al.*, 2021). An overview of inputs and outputs included in the ILCIDAF datasets related to the 19 Italian regions is reported in Table 1.

Table 1. Overview of inputs and outputs for olive production included in the ILCIDAF database

Macro-category	Input/Output	Unit	Data source
Fertilizer	Nitrogen	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
	Phosphorus pentoxide	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
	Potassium oxide	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
Pesticide	Copper	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
	Mancozeb	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
Packaging	Packaging (fertilizer)	kg	Moreno Ruiz *et al.*, 2022; Moreno Ruiz *et al.*, 2021
	Packaging (pesticide)	kg	Moreno Ruiz *et al.*, 2022; Moreno Ruiz *et al.*, 2021
Irrigation	Water	m^3	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021
	Electricity	kWh	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021

Macro-category	Input/Output	Unit	Data source
Fuel&lub	Diesel	kg	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021
	Lubricating oil	kg	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021
Transport	Transport of inputs	tkm	Eurostat, 2022; Moreno Ruiz *et al.*, 2021
Emission to air	Ammonia (from fertilizer)	kg	IPCC, 2006
	Dinitrogen monoxide (from fertilizer)	kg	IPCC, 2006
	Nitrogen oxides (from fertilizer)	kg	Zampori and Pant, 2019
	Copper (from pesticide)	kg	Zampori and Pant, 2019
	Mancozeb (from pesticide)	kg	Zampori and Pant, 2019
	Ammonia (from diesel)	kg	Nemecek and Kägi, 2007
	Benzene (from diesel)	kg	Nemecek and Kägi, 2007
	Benzo(a)pyrene (from diesel)	kg	Nemecek and Kägi, 2007
	Cadmium (from diesel)	kg	Nemecek and Kägi, 2007
	Carbon dioxide, fossil (from diesel)	kg	Nemecek and Kägi, 2007
	Carbon monoxide, fossil (from diesel)	kg	Nemecek and Kägi, 2007
	Chromium (from diesel)	kg	Nemecek and Kägi, 2007
	Copper (from diesel)	kg	Nemecek and Kägi, 2007
	Dinitrogen monoxide (from diesel)	kg	Nemecek and Kägi, 2007
	Heat, waste (from diesel)	MJ	Nemecek and Kägi, 2007
	Methane (from diesel)	kg	Nemecek and Kägi, 2007
	Nickel (from diesel)	kg	Nemecek and Kägi, 2007

Macro-category	Input/Output	Unit	Data source
	Nitrogen monoxide (from diesel)	kg	Nemecek and Kägi, 2007
	NMVOC (from diesel)	kg	Nemecek and Kägi, 2007
	Particulates (from diesel)	kg	Nemecek and Kägi, 2007
	Sulphur dioxide (from diesel)	kg	Nemecek and Kägi, 2007
	Zinc (from diesel)	kg	Nemecek and Kägi, 2007
Emission to water	Nitrate (from fertilizer)	kg	IPCC, 2006
	Phosphate (from fertilizer)	kg	Prasuhn, 2006
	Cadmium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Chromium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (heavy metals)	kg	Notarnicola *et al.*, 2023
	Lead (heavy metals)	kg	Notarnicola *et al.*, 2023
	Mercury (heavy metals)	kg	Notarnicola *et al.*, 2023
	Nickel (heavy metals)	kg	Notarnicola *et al.*, 2023
	Zinc (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (from pesticide)	kg	Zampori and Pant, 2019
	Mancozeb (from pesticide)	kg	Zampori and Pant, 2019
Emission to soil	Cadmium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Chromium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (heavy metals)	kg	Notarnicola *et al.*, 2023
	Lead (heavy metals)	kg	Notarnicola *et al.*, 2023
	Mercury (heavy metals)	kg	Notarnicola *et al.*, 2023

Macro-category	Input/Output	Unit	Data source
	Nickel (heavy metals)	kg	Notarnicola *et al.*, 2023
	Zinc (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (from pesticide)	kg	Zampori and Pant, 2019
	Mancozeb (from pesticide)	kg	Zampori and Pant, 2019
Waste	Packaging of chemicals	kg	Moreno Ruiz *et al.*, 2022; Moreno Ruiz *et al.*, 2021
	Lubricating oil	kg	CONOU, 2022; Moreno Ruiz *et al.*, 2021
	Pruning	kg	EC, 2021; Moreno Ruiz *et al.*, 2021

Impact Assessment

The impact assessment is carried out by applying the Environmental Footprint (EF) 3.0 method (Fazio *et al.*, 2018). In particular, eight impact categories are assessed according to the Product Category Rule (PCR) for virgin olive oil and its fractions (EPD International, 2010), i.e., acidification, climate change, photochemical ozone formation, eutrophication (freshwater), land use, water use, resource use (fossil), and resource use (minerals and metals).

Interpretation

The interpretation phase is performed through a hotspot analysis, which allows the identification and investigation of the inputs, outputs or processes causing the highest contribution to the environmental impacts in the analysed systems among the 19 Italian regions. In addition, the variability in terms of LCIA results due to the use of regionalised inventory datasets is evaluated through a descriptive statistics analysis (Sheard, 2018). The analysis is carried out by calculating basic statistical indicators, such as mean, standard deviation and coefficient of variation.

Results and Discussion

Figure 2 reports the results in terms of the percentage contribution to the environmental impacts related to the agricultural processes for olive production among the investigated Italian regions. Regarding the acidification impact category, the main findings point out that, in all regions, the main contribution, to the impact is caused by the ammonia emissions to air, for which the percentage contribution ranges from 74.34% for CAL to 81.86% for LIG. This is due to the direct emissions associated with synthetic fertilizer use. On the contrary, direct emissions related to diesel use in machinery and fertilizer production are responsible for the highest contribution in the climate change impact category. In particular, the

contribution to the climate change impacts respectively ranges from 59.33% for CAL to 69.48% for LIG, and from 11.79% for EMR to 21.21% for CAL. It is important to highlight that the impacts related to fertilizer production are connected to the background data derived from the Ecoinvent database. In addition, higher impacts related to the use of electricity in irrigation processes are also highlighted for APU, EMR, and FVG regions.

Emissions to air in terms of nitrogen oxides, due to diesel and fertilizer use, cause the highest impacts to photochemical ozone formation in all the Italian regions, with a percentage contribution higher than 64%. Concerning eutrophication (freshwater), the main impacts are connected to the use of fertilizers, for which the highest contribution emerges for CAL (91.15%), and to the production of copper as a pesticide, which causes the main impacts in the EMR region (22.48%). Focusing on land use and water use impact categories, fertilizers and pesticide production are responsible for the highest impacts in all the investigated regions. Higher impacts in terms of land and water use are also related to the irrigation process. It is important to underscore that, according to the ILCIDAF datasets for olive production, electricity and water use for irrigation are only accounted for those regions with a geographical conformation characterised by plains, as reported in ISTAT (2023). Results related to the resource use impact categories highlight that the main impacts are due to input production for which, as previously reported, background data are gathered by the Ecoinvent database. In particular, for fossil resource use the main contribution is connected to diesel and nitrogen fertilizer production which respectively cause the highest percentage contribution in EMR (51.13%) and LIG regions (20.27%). Remarkable impacts are also associated with transport activities, for which the contribution to the impact ranges from 8.31% for EMR to 18.29% for TAA. Furthermore, copper production mainly contributes to the minerals and metals resource use category, with values higher than 99% in all 19 Italian regions.

Overall, the results from the hotspot analysis point out that the main contribution to the potential environmental impacts is connected to fertilizers, fuel and direct emissions into the air. Furthermore, the main findings show high variability among regions in terms of the percentage contribution of inputs and outputs to the impacts, highlighting that the use of representative and regionalised data may strongly affect the LCA outcomes when agricultural processes are evaluated among different geographical contexts. This is also confirmed by the results obtained through the descriptive statistical analysis of the LCIA results (table 2). Indeed, the coefficient of variation, which is calculated by dividing the standard deviation by the mean, shows values that are higher than 43% in all the impact categories among the investigated Italian regions. In particular, the coefficient of variation ranges from 43.87% in climate change to 49.75% in eutrophication (freshwater). An in-depth analysis shows that, among the different regions, the minimum values in terms of environmental impacts in all categories are related to the TAA region, while the maximum emerges for the SAR region. In this regard, considering that, in ILCIDAF datasets for olive production, inputs related to each region are normalised to the average regional olive yield, a smaller amount of inputs is expected for those Italian regions characterised by a higher yield (e.G, for TAA the olive yield is equal to 5.2 tonnes per hectare), while a greater amount is accounted for regions with a lower yield (e.G, for SAR the olive yield is equal to 0.9 tonnes per hectare). Consequently, this variability may be reflected in the LCIA outcomes, further highlighting the importance of using data that are as much as possible representative of the investigated agrifood system.

Figure 2. Contribution analysis of inputs and outputs related to olive production in the 19 Italian regions under investigation (Characterisation results per 1 kg of harvested olives).

Table 2. Descriptive statistical analysis of the LCIA results

Impact categories	**Mean**	**StD**	**CV (%)**
Acidification [mol H+ eq]	2,61E-02	1.16E-02	44.39
Climate change [kg CO_2 eq]	8.46E-01	3.71E-01	43.87
Photochemical ozone formation [kg NMVOC eq]	3.98E-03	1.75E-03	43.99
Eutrophication (freshwater) [kg P eq]	6.59E-04	3.28E-04	49.75
Land use [Pt]	7.60E-01	3.50E-01	46.00
Water use [m^3 depriv.]	1.34E-01	6.49E-02	48.62
Resource use (fossil) [MJ]	6.51E+00	2.88E+00	44.25
Resource use (minerals and metals) [kg Sb eq]	2.30E-05	1.03E-05	44.99

Abb.: StD: Standard Deviation; CV: Coefficient of Variation

The usefulness of representative inventory data is also confirmed when LCIA outcomes using regionalised datasets from the ILCIDAF database are compared to those obtained using the sole dataset available for Italian olive production in Ecoinvent – Olive {IT}| olive production (figure 3). In particular, results underscore that using the Ecoinvent database instead of regionalised data may lead to an underestimation of the environmental impacts in all the investigated impact categories, except for land use and water use for an overestimation is pointed out. Indeed, the LCIA results vary from - 0.99 to about 342 times. The analysis also underscores that LCIA outcomes may strongly vary based on the investigated impact category to which specific direct or indirect emissions due to agricultural processes are classified. This is particularly true for the resource use (minerals and metals) category, in which a remarkable variability for certain regionalised datasets from the ILCIDAF database emerges when compared to the Ecoinvent dataset.

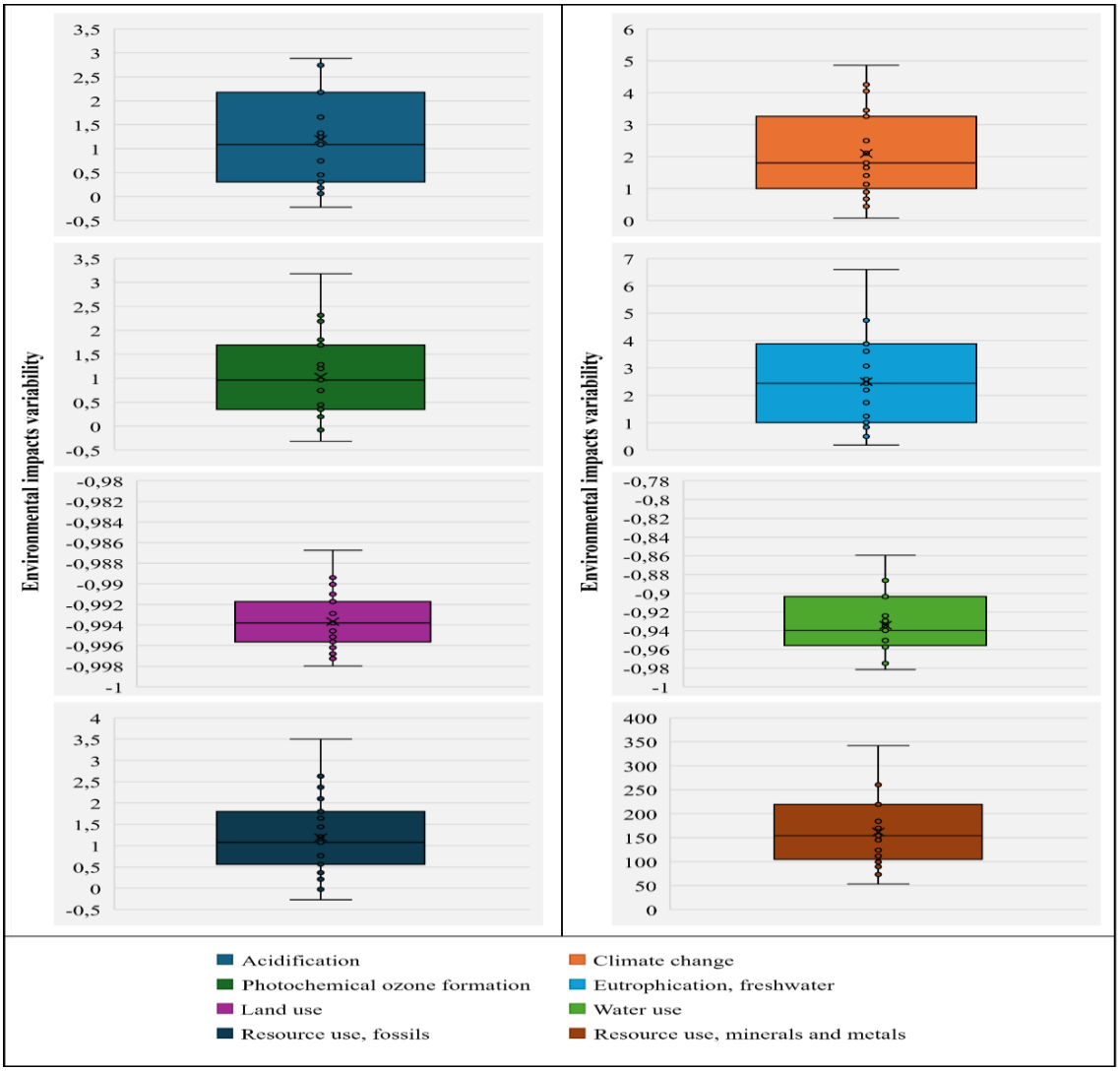

Figure 3. Environmental impact variability of regional olive production processes from the ILCIDAF database compared to the national average from the Ecoinvent database (the closer the value to 0, the lower the differences in terms of LCIA results between the two databases)

Conclusion

The aim of this study was to assess the potential environmental impact related to olive production in 19 Italian regions using regionalised datasets derived from the ILCIDAF database. The scope was to analyse and investigate the usefulness of representative LCI to be adopted in LCA studies related to agrifood systems. In this context, first, a hotspot analysis was carried out to point out which inputs, outputs or processes were responsible for the highest contribution to environmental impacts among regions. Then, a descriptive statistic analysis was performed in order to assess the variability in LCIA results occurring among regions in terms of environmental impacts. Lastly, the variability of the environmental impacts was also investigated comparing the LCA results obtained using regionalised data from the ILCIDAF database and the dataset related to olive production available in the Ecoinvent database. Results from the hotspot analysis highlighted that, in all the investigated Italian regions, the main contribution to the environmental impacts is due to direct emissions to air caused by fertilizers and diesel use, as well as due to fertilizers and fuel production. In addition, a significant statical variability emerged among the results. Indeed, a high coefficient of variation was identified for all the impact categories, ranging from 43.87% in climate change to 49.75% in eutrophication (freshwater). This confirms that the use of regionalised data, that are representative of the investigated agricultural or agrifood production systems, and account for all the intrinsic and extrinsic factors affecting them, may strongly characterize the results of a LCA study. This is also pointed out by the comparative analysis between ILCIDAF and Ecoinvent datasets. Indeed, using the Ecoinvent dataset instead of regionalised LCIs may cause an underestimation of the environmental impacts in most of the investigated impact categories.

The results from this study point out the importance of using representative data in LCA studies applied to agricultural processes. Despite this, future research should be oriented on evaluanting the uncertainty associated with the LCIA results obtained using such representative data. This would allow a more comprehensive understanding of the usefulness, accuracy and reliability of regionalised inventories available in the ILCIDAF database. In addition, futher analyses should be focused on expanding the system boundaries by also including the olive oil production, distribution, use and endof-life phase.

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Posters

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Beyond Sustainable Development Goals for Building Societal Prosperity and Foundation: Insights for a Systematic Review

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Abstract

A key question in achieving global sustainable development is how to build social foundation within planetary boundaries. Among the three pillars of sustainability, the social dimensions have gained relatively limited attention than other pillars. The Sustainable Development Goals (SDGs) and other frameworks (e.g., safe and just space frameworks) have conceptualised multiple social dimensions of sustainability. Recent studies have focused on whether indicators or thresholds are being met in countries and regions. However, there remains substantial inconsistency across frameworks in terms of definitions, indicators and thresholds. A holistic analysis of related frameworks is still lacking. This study therefore undertakes a systematic review of the existing literature on socio-economic aspects of sustainable development. It starts with about 21,777 article records for an initial screening based on a broad keyword search in the Scopus and Web of Science databases. We use a machine learning tool to further screen the searched literature and finally develop indicators that comprehensively represent the social foundations. Due to the large sample size, this review also captures the dilemmas and conflicts of sustaining social livelihoods and planetary boundaries. Our study analyses the interactions between social and environmental dimensions in different contexts. It provides insights to assess the alignment and potential extension of current sustainability frameworks. Our findings aim to make the concepts of social foundations more comprehensive and inclusive within the planetary boundaries.

This abstract relates to the SDG1: End poverty in all its form everywhere, in particular targets 1.1, 1.2, 1.3, and the SDG8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. This study explores the essential indicators that measure the social foundations for long-term sustainability, providing insights to support the SDGs 2030 agenda. It echoes with the theme of this conference on sustainable livelihoods from mountain to ocean, and highlights the connectivity between people's livelihoods and environmental resources.

Track 2 Education for Sustainability

2a. Provision, Quality of and Access to Education

Abstracts

Submission ID: 11

Education on Sustainability, Circularity, and Responsibility: A Case Study from EIT Raw Materials Courses

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Abstract

The rational management of raw materials including metals, energy, chemicals and industrial raw materials as well as water and biomass is a key element of a circular economy, and an important issue reflected in sustainable development goals. In the policies of many countries and organizations, there is an expectation that the environmental impact throughout the life cycle of raw material use will be reduced. Material flows and resource productivity indicators play a central role in monitoring the changing patterns of resource use. Companies, including those in the mining sector, have already published information regarding their sustainability performance. Furthermore, in 2024, the EU Corporate Sustainability Reporting Directive (CSRD) will mandate more comprehensive sustainability and environmental, social, and governance (ESG) reporting by large companies. European Sustainability Reporting Standards (ESRS) will lay out the disclosure obligations of companies including mining, processing and recycling. Therefore, new practical knowledge and case studies are needed to understand and learn these requirements and procedures, which are now being implemented also in many mining countries outside the EU All these rapid changes and new requirements necessitate acquiring new knowledge for staff in existing companies, administration and universities. The new and updated education programme for different types of courses and lectures, i.e., EIT-Labelled Master Programme: lifelong learning, PhD school, etc. courses can be supported by EIT Raw Materials within The Raw Materials Academy. Various conventional, non-conventional, and digital tools have already been proposed for individuals already working in the raw materials sector, as well as students and PhD students, not only from Europe. In most of them, the goal was not only to enhance practical and theoretical knowledge but also to raise awareness regarding corporate social responsibility, sustainable development, and responsible mining. Additionally, there was a focus on promoting the greater adoption of clean and environmentally friendly technologies and industrial processes. The paper aims to analyse and review both good practices in teaching methods and the scope and educational content of proposed courses and lectures, taking into account the issues of circularity and sustainability. Drawing from my own experience and students' evaluations, the paper includes a SWOT analysis and recommendations for further educational activities.

Submission ID: 268

Empowering Narratives: A Storytelling Approach to Sustainable Menstrual Hygiene in Rural India

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Abstract

The sustainability of our planet depends on minimizing environmental harm, with improper sanitary pad disposal in rural India being a pressing issue. This study is focused on addressing the issue of natural resource depletion and pollution resulting from this problem, specifically for girls aged 12-15 at the Government Higher Primary School in Mandihal village, Dharwad Taluka, Dharwad district, Karnataka state, India.

The project aims to introduce reusable sanitary pads as a sustainable solution and foster community participation and stakeholder engagement through group discussions and targeted awareness sessions. It will also emphasize the importance of collaborative learning, with student experiences crucial in facilitating knowledge transfer and partnerships.

Aligned with Sustainable Development Goal (SDG) 3 (Good Health and Well-being), the project signifies a broader commitment to education for all and lifelong learning. By integrating storytelling and lived experiences into discussions about hygiene and care, the initiative educates and addresses social and cultural issues embedded in sustainable practices. The storytelling approach creates a dynamic space for shared experiences, contributing to a holistic understanding of menstrual hygiene.

This initiative is an inclusive and innovative approach to addressing a specific challenge, emphasizing the power of storytelling in shaping attitudes and behaviours. If successful, it could be a scalable model for other communities, aligning with principles of community participation, stakeholder engagement, and sustainable alternatives. The project aims to establish a replicable solution, fostering collaborative learning and contributing to the health of adolescent girls and the broader environmental sustainability landscape.

Full Papers

Submission ID: 74

Attributes of Educational Partnerships Designed to Create Global Changemakers: A Literature Review

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Abstract

The purpose of this paper is to conduct a systematic literature review on the attributes of educational partnerships designed to create global changemakers. Changemakers strive to create positive impacts in society. The results from this literature review show common attributes of educational partnerships designed to create global changemakers. These attributes include collaboration and connections, a need for complex systems that follow a framework, committed leadership that has expertise, forward-thinking mentality, presence of quality that evolves and creates value, engagement fostered through innovation and ideas, trust communicated through transparency and ethics, and a global vision. Uncovering attributes present in educational partnerships could provide insight into systems needed to be present to sustain educational partnerships. In communities where parents have access to school choice, schools that offer a curriculum which focuses on educating students as future global changemakers may provide an attractive quality for enrolment. This research follows United Nations Sustainable Development Goal Quality Education Target 4.7, which states that providing a quality education promotes "a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development."

Introduction

Four years ago, the COVID-19 greatly impacted our global society. Many families were bound to their neighbourhoods, as travel was restricted to only necessary activities such as shopping for food and seeing a physician, and travel between communities, regions and nations was either limited or completely forbidden (Zezima *et al.*, 2020). Nearly 1.6 billion students in 190 countries were homebound, either not receiving any education at all due to lack of internet access, receiving instruction remotely, or attending school through a hybrid platform of in person instruction and remote learning (UNESCO, 2021). Teachers were without the experience and training required to present curriculum remotely and were struggling to cover academic standards (UNESCO, 2020). The global pandemic was heralded as the "worst education crisis in a century" and stalled the progress toward achieving the United Nations Sustainable Goal 4, "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by the target year of 2030 (The World Bank, 2021). When the COVID-19 pandemic forced students in the United States receive their education remotely or in a socially distanced hybrid learning environment, some parents of students enrolled in private schools withdrew their children because they felt the quality of education dropped (McCluskey, 2021).

The pandemic's global impact on educational institutions brought visibility to "the enormous potential for innovation that is dormant in many education systems" (Vegas and Winthrop, 2020) as awareness about student access to an innovative curriculum that prepares students for a global future is growing among the customer base of universities (Helmold, 2021). One form of accessing an innovative curriculum in educational institutions is through the development of global partnerships between schools in the form of "collaboration networks" that foster exchange programs for students and professional development

for educators through a symbiotic sharing of information (Snyder *et al.*, 2000). Students who participate in global partnership learning experiences report that it "enhances their own intercultural experience and learning and develops their ability to work across cultures and communicate with partners (Edge and Khamsi, 2012)." Thus, the purpose of this paper is to conduct a literature review on the attributes in educational partnerships designed to create global changemakers.

Methodology

The purpose of this paper is to conduct a systematic literature review on the attributes in educational partnerships designed to create global changemakers. The importance of conducting this systematic literature review was to learn what was written about the topic and where there are gaps in the literature. There is general consensus that a systematic literature should follow these steps: 1) Identify the problem that is to be studied; 2) Identify keywords that are relevant to the study; 2) search in online databases and in-person library databases using the keywords selected; 3) quickly do an initial sort of the literature for relevancy; 4) read the whole text for relevancy; 5) extract data from the literature; 5) analyse the data that was extracted; and 6) report the findings (Creswell and Creswell, 2018, Pollock and Berge, 2018, Štrukelj, 2018, Xiao and Watson, 2019). For this systematic literature review, steps one through six were followed, with the modification of only searching in online databases.

The systematic literature review was conducted using the following databases accessed through Mid Sweden University's online library system: Academic Search Premier, Business Source Complete, Educational Resources Information Center (ERIC), and Web of Science Core Collection. I was able to use EBSCOhost, an online library database to combine my search through Academic Search Premier, Business Source Complete, and ERIC. In EBSCOhost, my search mode was Boolean/Phrase, and my expanders were "apply related words", "also search within the full text of the articles" and "apply equivalent subjects." My limiters were "scholarly (peer reviewed) journals", "date published 2016-2021", "language English", "full text", and "references available." The special limiters for Academic Search Premier were "Publication Type: Periodical", "Document Type: Article", and "PDF Full Text." The special limiters for Business Source Complete were "Publication Type: Academic Journal", "Document Type: Article", and "PDF Full Text." The special limiters for ERIC were "Journal Article (EJ)", "Publication Type: Journal Articles", "Education Level: All", "Publication Type: Journal Articles", "Intended Audience: All", and "What Works Clearinghouse (WWC) Reviewed: Meets Evidence Standards without Reservations.". The limiters for Web of Science Core Collection were "All Open Access", "Publication Years: 2016-2021", "Document Type: Articles", and "Languages: English."

Initially, the search used the string "quality management" AND "education" AND "innovative" AND "sustainable" AND "global partnerships." The EBSCOhost yielded one result which was discarded for relevance and Web of Science yielded no records. It was evident that the search string was too restrictive, so the search string was modified to "innovative" AND "partnership" AND "education" AND "global citizen." EBSCOhost yielded 3 results of which all were discarded for relevance and Web of Science yielded 5 results which were discarded for relevance. I shifted my focus to the core theme of my study which is innovative sustainable partnerships between organizations. In EBSCOhost, I typed "creating sustainable international organizational partnerships." This search yielded 424 articles. Titles were scanned for relevance which narrowed the articles down to 24. The abstracts were read, after which the articles were narrowed down to 18. The same search on Web of Science yielded 6 articles, of which 2 were retained for

relevance. The total amount of articles retained for this literature review was 20. After reading the articles, 5 were discarded due to relevance, leaving 15 in the final count see Figure 1 and Table 1.

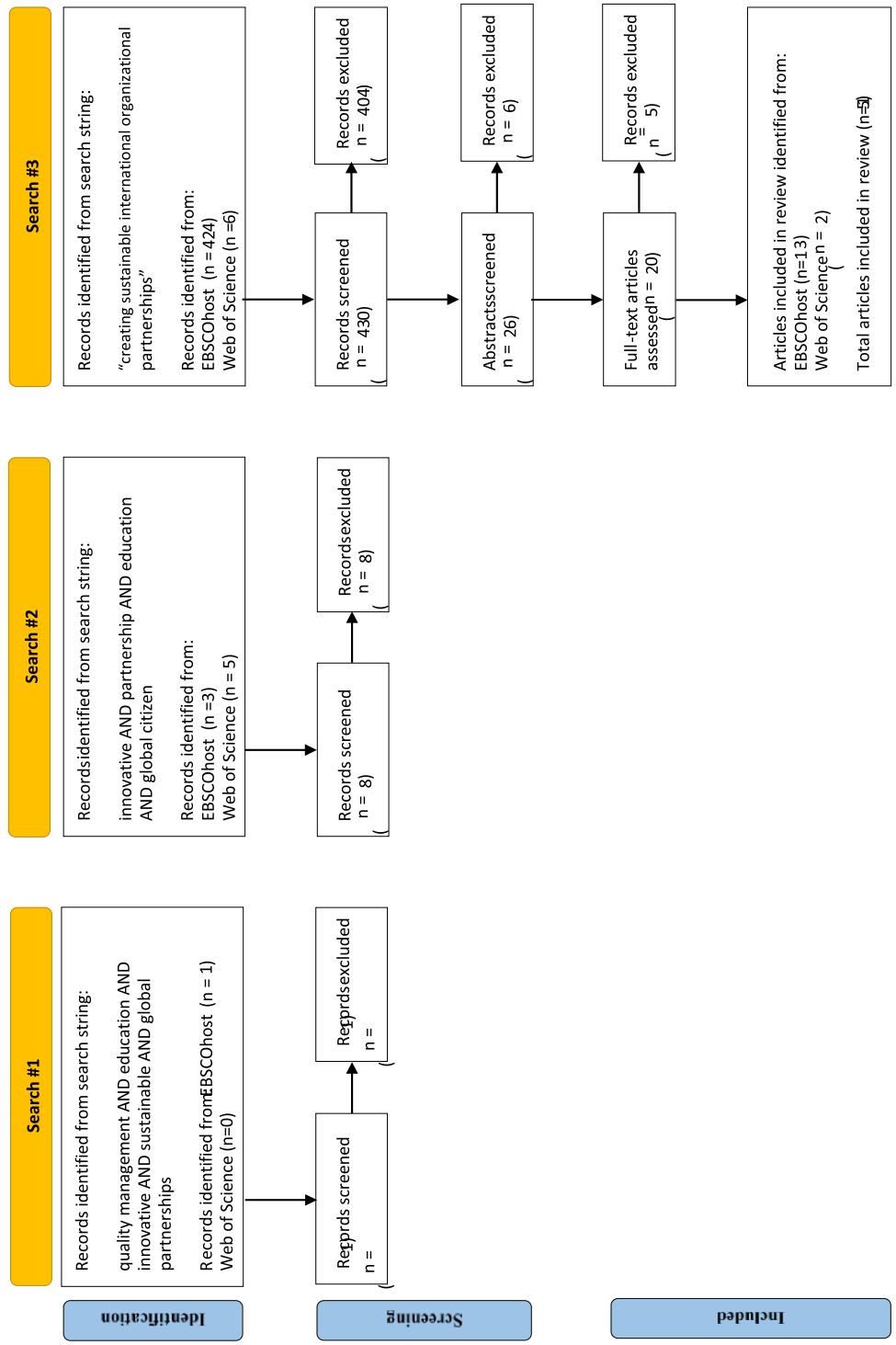

Figure 1 . Flow chart showing systematic literature review process modified from PRISMA 2020 flow diagram.

A search for key themes in the articles was done by reading the articles and highlighting dominant keywords. Authors described trust (Chen *et al.*, 2018; Davis, 2016; Haywood *et al.*, 2019; Spraul and Thaler, 2020; Stachova *et al.*, 2019; Waterval *et al.*, 2018; Xiong *et al.*, 2019), collaboration (Colaner *et al.*, 2018; Davis, 2016; Hassan *et al.*, 2019; Haywood *et al.*, 2019; Hunter *et al.*, 2018; MacDonald *et al.*, 2019; Purcell *et al.*, 2019; Spitz *et al.*, 2021; Stadtler, 2018), and communication (Chen *et al.*, 2018; Spitz *et al.*, 2021; Spraul and Thaler, 2020; Waterval *et al.*, 2018; Watts *et al.*, 2020; Xiong *et al.*, 2019), as essential components of quality sustainable partnerships between organizations.

To further analyse the literature for themes of trust, collaboration, and communication or discover if there were other themes regarding sustainable structures which create value between organizations, Snyder's (Snyder, 2018) "List, Cluster, Label" method was employed. Originally intended for brainstorming, in which ideas are listed, clustered together into groups, and then labelled with a descriptor word, this method can be transferred to categorizing words for the purpose of discovering patterns or themes in texts.

A secondary analysis for themes in the literature was conducted to cross-check initial inferred themes of keyword data. The word frequency counter, www.wordclouds.com, was used to generate word lists from the 15 articles. To start, all articles were combined into one Portable Document Format (PDF) file. The references, authors, headers, page numbers, author biographies, and acknowledgements were removed as the focus of the word count would be on the title, abstract, and the content portion of the articles. When the articles were combined, the total word count was 144 245. After the file was edited, it contained 114 680 words and was uploaded to www.wordclouds.com for analysis. The filter "ignore stop words" was selected. This filter removed common words such as "a", "and", "or", "the", etc. Words that were listed less than 5 times, were also eliminated. The word frequency counter retrieved 2500 words, with the highest count of 543 for the word "partnership" and the lowest count of "5" for "Year." The words were exported as a comma-separated values (csv) file, downloaded, and uploaded into Microsoft Excel. The words were analysed and word groups containing nondescript words such as simple verbs, prepositions, numbers, abbreviations, conjunctions, simple adverbs, and names (for example "can", "around", "five", "e.g.", "although", "also", "Falstaff") were removed. The 2275-word groups remained in the list. Nondescript words, words which could have dual meanings, proper nouns and abbreviations (except for the abbreviation for Sustainability Development Goals (SDGs)) were removed (for example, "potentially", "term", "Netherlands", "CSR"). The 367-word groups remained in the list.

Words were grouped together based on similar root words. This was done by creating a search string with the root word and searching for that string in Excel. For example, the search string "creat*" found the words "create", "created", "creation", "creating", "creative", "creates", "co-create", and "cocreation." After all words were sorted and grouped, a list of 119-word groups remained (Table 2). Each search string was converted into a word that represented each group. For example, the "creat*" search string was replaced by the word "create" as a representative of that group (Table 3). The 119-word representatives were clustered according to similar meanings. For example, "partnerships" was put in a cluster with "alliance", "collaboration", "integration", "cooperation", etc. (Figure 2). After this sorting, 9 clusters of word groups were labeled: "partnerships", "systems", "leadership", "stakeholders", "quality", "engagement", "trust", and "global" (Table 4).

Table 1. Articles and Publications Selected for Systematic Literature Review

Author	Date	Title	Publication
Chen, C. *et al.*	2018	Review of social responsibility factors for sustainable development in public-private partnerships	Sustainable Development
Colaner, N. *et al.*	2018	Dialogic Collaboration across Sectors: Partnering for Sustainability	Business & Society Review
Davis, J.P.	2016	The Group Dynamics of Interorganizational Relationships	Administrative Science Quarterly
Hassan, M.M, *et al.*	2019	Streamlining non-governmental organizations'programs towards achieving the sustainable development goals: a conceptual framework	Sustainable Development
Haywood, L.K, *et al.*	2019	The Sustainable Development Goals in South Africa: Investigating the Need for Multi-stakeholder partnerships	Development Southern Africa
Hunter, M.A., *et al.*	2018	SongMakers: an industry-led approach to arts partnerships in education	Arts Education Policy Review
MacDonald, A, *et al.*	2019	Multi-stakeholder Partnerships for Sustainability: Designing Decision-Making Processes for Partnership Capacity	Journal of Business Ethics
Purcell, W.M, *et al.*	2019	Universities as the engine of transformational sustainability toward delivering the sustainable development goals.	International Journal of Sustainability in Higher
Spitz, G, *et al.*	2021	Motives matter: the relation between motives and interpartner involvement in nonprofit-business partnerships	Nonprofit Management and Leadership
Spraul, K. and Thaler, J.	2020	Partnering for good? An analysis of how to achieve sustainability-related outcomes in public-private partnerships	Business Research
Stachova, K, *et al.*	2019	External Partnerships in Employee Education and Development as the Key to Facing Industry 4.0 Challenges	Sustainability
Stadtler, L.	2018	Tightrope Walking: Navigating Competition in Multi-Company Cross-Sector Social Partnerships	Journal of Business Ethics
Waterval, D.G.J, *et al.*	2018	Twelve tips for crossborder curriculum partnerships in medical education	Medical Teacher
Watts, P.I, *et al.*	2020	Sustaining global partnerships for simulation integration: lessons from the field	International Nursing Review
Xiong, W, *et al.*	2019	Governing public-private partnerships: a systematic review of	Australian Journal of Public

Author	Date	Title	Publication
		case study literature	Administration

Table 2. Word Groups with Search Strings, Sorted by Word Count

Total Word Count	Search String	Words Included	Total Word Count	Search String	Words Included
1487	partner*	partnership, partnerships, partners, partner, interpartner, multipartner, Partnership, Partnerships, partnerhip's, partner's, Partners, inter-partner, Partner	65	coordinat*	coordinate, coordinating, coordinated, coordinator, coordination
689	collabor*	collaboration, collaborative, collaborations, collaborate, collaborating, Collaborative, collaboratively, Collaboration, collaborators	64	long-term	long-term
661	sustain*	sustainable, sustainability, sustainability-related, Sustainable, Sustainability, sustained, sustain	64	perspective*	perspectives, perspective
507	develop*	develop, development, Development, developed, developed, developing, developments	64	invest*	investors, invested, invest, investing, investment
472	organ*	organization, organizations, organizational, interorganizational, organisations, Organizations, organized, organization's, inter-organizational, Organization, organizing, organization's, Organizational	63	roles	roles
397	business*	Business, businesses, nonprofit-business, Business, Businesses, business's	61	plan	plan
385	relat*	relationships, related, sustainability-related, relationship, relational, relational-based, causerelated, relation, relations, relate,	61	monitor*	monitor, Monitoring, monitoring

Total Word Count	Search String	Words Included	Total Word Count	Search String	Words Included
		interrelationships, interrelated, relates			
339	compan*	company, companies, Company, multi-company, company's, multicompany, Companies	60	uni*	unified, United
333	manag*	managers, management, manager, Management, managerial, manage, managing, Manager, managed	59	needs	needs
280	innovat*	innovation, innovative, innovations, Innovation, innovate	54	transform*	transformational, transformative, transformation
253	SDG*	SDG, SDGs	53	alliance*	alliances, alliance
206	compet*	competition, competitors, competing, Competition, competition's, competitive	51	enterprise*	enterprises, enterprise
201	motiv*	motives, motivation, motivated, motive, motivations, motivate, Motives	50	world*	world, World, worldwide, world's
200	program*	program, programs, program's, Program	49	initiative*	initiatives
188	stakeholder*	stakeholders, stakeholder, multistakeholder, Multistakeholder, multi-stakeholder	49	risk*	risks, risk
181	system*	system, systematic, Systems, systemic, systems	43	expert*	expert, experts, expertise
181	achiev*	achieving, achieved, achievement, achievements, achieve	43	ethic*	ethical, ethics
180	knowledge	Knowledge	39	transparen*	transparent, transparency
180	structur*	infrastructure, structural, structures, Structural, semistructured, structured, structure	38	idea*	idea, ideas
175	lead*	lead, leaders, leading, leads, Leadership, leadership	38	dependen*	interdependence, interdependent, dependent
164	goal*	goal, Goals, goals	35	cycl*	cycle, cycling
162	shar*	sharing, share, shared	31	moral	Moral, moral
155	involv*	involvement, involve, involving involves	28	solutions	solutions

Total Word Count	Search String	Words Included
148	engag*	engage, engaged, engagement
146	impact*	impacts, impactful, impact
145	design*	designed, designs, designing, design
144	strateg*	strategies, strategy, Strategic, Strategy, strategic
140	network*	network, networking, Network, networks
139	creat*	create, created, creation, creating, creative, creates, co-create, co-creation
137	trust*	Trust, trust
135	chang*	changes, changing, Change, change
132	deci*	decisions, decision, decided, decisionmaking, DecisionMaking, decision-making
132	success*	Success, successful, success
124	market*	markets, marketing, marketplace, market
113	community	Community, community
111	understand*	understand, Understanding, understanding
110	value*	values, value
110	opportun*	opportunity, opportunities
106	Society	society
102	responsib*	responsibilities, responsible, responsibility
98	communicat*	communicate, Communication, communication
98	experience*	experiences, experience
96	integrat*	integrated, integrate, integrative, integrates, integration
95	perform*	perform, performance
95	improv*	improve, improving, improved, improve, improvement
93	benefi*	benefit, beneficial, beneficial, benefits
90	Future	Future, future
89	qualit*	qualitative, quality
27	growth	growth
23	expectations	expectations
22	perception*	perception, perceptions
22	reputation*	reputation, reputational
21	costs	costs
21	demands	demands
21	inspir*	inspired, inspire, inspiration
19	customers	customers
18	accountability	accountability
17	facilitate	facilitate
16	inclusive	inclusive
15	well*	wellbeing, well-being
14	citizen	citizen
14	intellectual	intellectual
14	promoting	promoting
13	complementary	complementary
12	contractual	contractual
12	openness	openness
12	Project	Project
12	prosperity	prosperity
12	evolv*	evolve, evolution
11	confidence	confidence
11	genuine	genuine
11	mutually	mutually
11	participants	Participants

Total Word Count	Search String	Words Included	Total Word Count	Search String	Words Included
83	objective*	objective, objectives	11	participatory	participatory
81	cooperation	Cooperation, cooperation	10	inclusion	inclusion
79	global*	Global, globally, global	9	insight	insight
78	mechanism*	mechanism, mechanisms	9	production	production
78	interact*	interaction, interact, interactions	9	satisfaction	satisfaction
77	complex*	complexity, complex	9	synergies	synergies
76	evaluat*	Evaluation, evaluations, evaluation	8	specialists	specialists
73	framework	frameworks, framework	6	interconnected	interconnected
70	international*	International, Internationalization, internationally, international	6	intertwined	intertwined
68	train*	training	6	problem-solving	problem-solving
66	financ*	finance, financial, finances, financial	5	corporations	corporations
65	commit*	commitments, committed, commitment			

Table 3. Search Strings with Assigned Word Representative, Sorted Alphabetically

Search String	Word Representative	Search String	Word Representative	Search String	Word Representative
accountability	accountability	future	future	partner*	partnerships
achiev*	achieve	genuine	genuine	perception	perception
alliance*	alliance	global*	global	perform*	performance
benefi*	benefit	goal*	goals	perspective*	perspective
business*	business	growth	growth	plan	plan
chang*	change	idea*	ideas	problem-solving	problem-solving
Citizen	citizen	impact*	impact	production	production
collabor*	collaboration	improv*	improvement	program*	program
commit*	commitment	inclusion	inclusion	Project	project
communicat*	communication	inclusive	inclusive	promoting	promoting
community	community	initiative*	initiatives	prosperity	prosperity
compan*	companies	innovat*	innovation	qualit*	quality
compet*	competitive	insight	insight	relat*	relationships
complementary	complementary	inspir*	inspired	reputation*	reputation
complex*	complex	integrat*	integration	responsib*	responsibility
confidence	confidence	intellectual	intellectual	risk*	risk
contractual	contractual	interact*	interactions	roles	roles
cooperation	cooperation	interconnected	interconnected	satisfaction	satisfaction
coordinat*	coordination	international*	international	SDG*	SDGs

corporations	corporations	intertwined	intertwined	shar*	shared
Costs	costs	invest*	investment	society	society
creat*	create	involv*	involvement	solutions	solutions
customers	customers	knowledge	knowledge	specialists	specialists
Cycle	cycle	lead*	leadership	stakeholder*	multi-stakeholder
deci*	decision-making	long-term	long-term	strateg*	strategic
demands	demands	manag*	managers	structur*	structure
dependen*	interdependence	market*	market	success*	success
design*	design	mechanism*	mechanisms	sustain*	sustainability
develop*	development	monitor*	monitoring	synergies	synergies
engag*	engagement	moral	moral	system*	systems
enterprise*	enterprise	motiv*	motives	train*	training
ethic*	ethics	mutually	mutually	transform*	transformation
evaluat*	evaluation	needs	needs	transparen*	transparency
evolv*	evolve	network*	networks	trust*	trust
expectations	expectations	objective*	objectives	understand*	understanding
experience*	experience	openness	openness	Uni*	united
expert*	expertise	opportun*	opportunities	value*	value
facilitate	facilitate	organ*	organizations	well*	well-being
financ*	financial	Participants	participants	world*	world
framework	framework	participatory	participatory		

After reading the articles and inferring three themes of trust, collaboration and communication were core characteristics of sustainable partnerships between organizations that create value for all stakeholders. The data were compared with the "List, Cluster, Label" word analysis using an online program, www.wordclouds.com, which identified nine core themes: partnerships, systems, leadership, stakeholders, quality, sustainability, engagement, trust, and global. The resulting list, of which the characteristic "trust" is duplicated, and "collaboration" and "communication" are both in the "partnership" cluster, still contains the nine core themes identified through the "List, Cluster, Label" word analysis (Table 4).

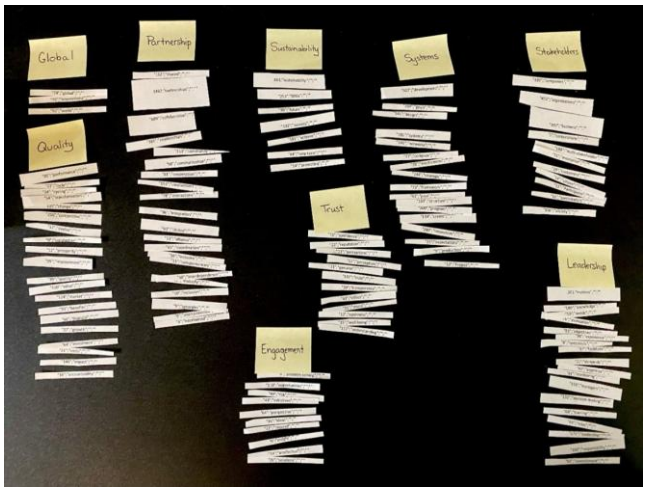

Figure 2. Labeled Word Clusters with Number Count of Each Word Group.

Table 4. Labels Assigned to Final Cluster Groups Sorted by Word Count

Word Count	Label	Cluster
3631	Partnership	alliance, collaboration, communication, community, complementary, cooperation, coordination, inclusive, integration, interactions, interconnected, interdependence, intertwined, involvement, mutually, partnerships, relationships, shared, synergies, united
1994	Systems	complex, design, development, expectations, framework, goals, mechanisms, networks, plan, production, program, project, strategic, structure, systems
1785	Leadership	decision-making, demands, commitment, evaluation, experience, expertise, facilitate, knowledge, leadership, managers, monitoring, motives, needs, objectives, responsibility, roles, specialists, training
1613	Stakeholders	business, citizen, companies, corporations, customers, enterprise, multi-stakeholder, organizations, participants, participatory, society
1395	Sustainability	achieve, future, long-term, promoting, success, sustainability, SDGs
1225	Quality	accountability, benefits, change, competitive, costs, cycle, evolve, financial, growth, impact, improvement, investment, market, performance, prosperity, quality, satsifaction, transformation, value
807	Engagement	create, engagement, ideas, initiatives, innovation, insight, inspired, intellectual, opportunities, perspective, problem-solving, risk, solutions
454	Trust	confidence, ethics, genuine, moral, openness, perception, reputation, transparency, trust, understanding, well-being
199	Global	global, international, world

The nine themes were separated into two groups: systemic in Figure 2 and engagement in Figure 3. The systemic group consists of characteristics of the partnership that, on the surface, seem perfunctory in nature. Superficially, these themes are either mechanical or analytical in the way they behave. They may use rules or definitions as part of their identity. The systemic group themes in Figure 3 are partnerships, systems, leadership, stakeholders, quality, and global. The engagement group in Figure 4 is fluid, seemingly without order or an easily identifiable structure, and contain the themes engagement and trust.

Figure 3. Word Frequency Cloud Illustrating Words from Systemic Group

Figure 4. Word Frequency Cloud Illustrating Words from Engagement Group

Results

Colaner *et al.* (2018), describes partnerships as achievable in three stacked levels. The first level is very superficial, where one organization shares resources with another. The second level is where one organization is using the other to help fill a deficit in "competencies or expertise." The third level is where both organizations are working together in the leadership position to achieve a common goal. This literature review focuses on the definition of partnership in the third level.

The interplay between the systemic partnership creation and the engagement of the members in the partnership is complex and interlocked. It is challenging to pick out one theme without including the other. According to articles researched for this literature review, partnerships must contain a baseline of trust (Chen *et al.*, 2018; MacDonald *et al.*, 2019). The establishment of trust occurs as a result of and propagates the development of openness and transparency between the partners (MacDonald *et al.*, 2019; Chen *et al.*, 2018; Haywood *et al.*, 2019). Transparency is enforced through an establishment of "structured networks" of guidelines regarding mutual expectations in the partnership (Stachova *et al.*, 2019; Haywood *et al.*, 2019; Waterval *et al.*, 2018) and prescribed roles for each member to play (Haywood *et al.*, 2019). Transparency is expressed through "fair and open discussions" (Spraul and Thaler, 2020) and providing "consistent feedback" (Watts *et al.*, 2020) in person and/or through organized communication systems such as websites, newsletters, and email (MacDonald *et al.*, 2019). The interlocking mechanism of trust and a structured network of guidelines builds relationships where knowledge is shared willingly (MacDonald *et al.*, 2019, Haywood *et al.*, 2019). This ease of communication effectively promotes effective collaboration during decision making, which is central to the success of partnerships (MacDonald *et al.*, 2019). When this model of a partnership is established between a primary school and an outside organization, it improves "learning outcomes", "engagement in learning", "motivation to learn", and creates value in integrating education and industry (Hunter *et al.*, 2018).

Discussion

There have been calls for a change in the educational systems throughout the world, in that the current educational models are not preparing our students to become problem solvers and innovators as adults in a global crisis, stating that change in schooling is desired because we are needing to prepare our students for an "increasingly interdependent world," an aspect in which our educational model is lacking

(Senge, 2003) and that "our educational system is increasingly coming under fire for not preparing our children adequately to meet the demands of the future (Senge and Kim, 2013)." He indicates that "changes of the sort we have been working for in business will probably not be sustainable without parallel changes in public education (Senge, 2000).

The theme of collaboration in the creation of partnerships has emerged as a way to prepare students for their growth into innovative global problem-solvers. Senge specifically calls for the establishment of partnerships in education in that they "might bring perspectives and capabilities to educators seeking to produce fundamental change in schools (Senge, 2000)." The Brookings Institution's report "Beyond reopening schools: How education can emerge stronger than before Covid-19," states that quality education is needed and there "is an opportunity to identify new strategies, that if sustained, can help young people get an education that prepares them for our changing times." Brookings calls for schools to "allow for allies in the community… to reinforce, complement, and bring to life learning experiences in and outside the classroom." The formation of these partnerships would help to "reorganize and adapt to the learning that takes place beyond its walls," sustaining an ecosystem of learning and support. Figure 5 shows a "Powered up Schools" model placing "the school at the center of a community ecosystem of learning and support." It is worth noting that this model indicates the importance of educational partnerships as three of the five key elements are Out of School Programs, Employers and Business, and Community Institutions (Vegas and Winthrop, 2020).

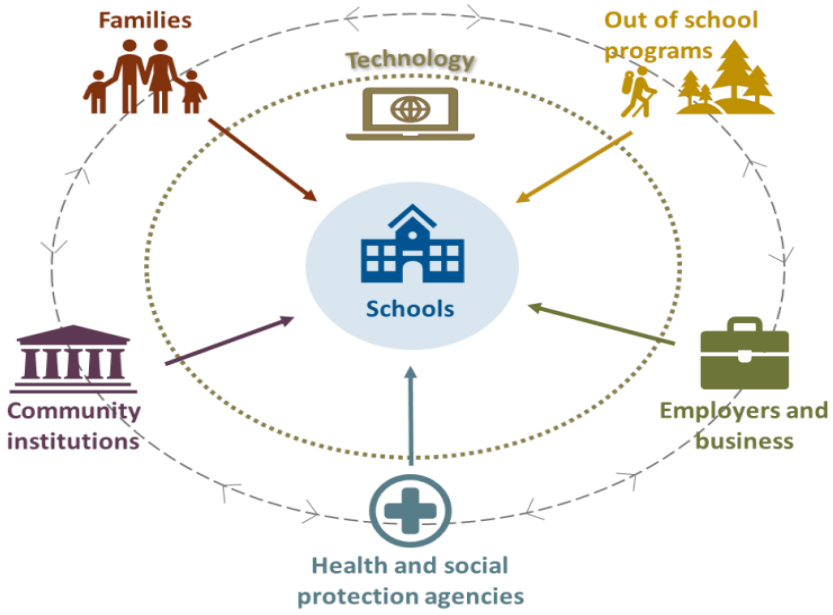

Figure 5. "Powered up Schools" model adapted from the Office of Elementary and Secondary Education (OESE) by The Brookings Institution (Vegas and Winthrop 2020)

The Organisation for Economic Co-operation and Development (OECD) charges that schools should "unleash innovation" because "those who were able to create alliances, to build collaborations across stakeholders in the public and private sector, to use rapid feedback cycles to guide their work with

knowledge of conditions on the ground, to engage with peers to rapidly mobilise knowledge, and to revise and adjust regulations to quickly support essential adaptations to new conditions were able to foster the necessary innovation, collaboration and flexibility to sustain educational opportunity (Reimers and Schleicher, 2020)." The International Baccalaureate Programme, a framework for worldwide school assessment states that "the aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world." This mission is supported by a call for collaboration and partnership in the Standards and Practices for Lifelong Learners, "Students exercise the flexibility, perseverance and confidence they need to bring about positive change in the wider community and beyond" and for Leadership in "supporting student involvement in service as action and implementing the personal or community project (2020)."

There are calls for using "multidimensional systems thinking" which fosters an "active interchange of ideas, global cooperation in research and development, and the rapid dissemination of best practices across countries" creating "global knowledge networks (Sachs, 2015)." Regarding universities becoming hubs for "effective problem solvers," the United Nations Sustainable Development Solutions Network (SDSN) was created as an outreach organization that "aims to link universities, businesses, and other knowledge institutions around the world in the common challenge of finding solutions to sustainable development (Sachs, 2015)." Senge suggests that educational institutions should adopt a living system model of operating so they become human communities and not machines on an assembly line producing graduates (Senge *et al.*, 2008), and that "executive leaders… must develop strategies for building a sustainable competitive advantage, which means creating an environment in which people are open to new ideas, responsive to change, and eager to develop new skills and capabilities (Senge, 1996)." Senge does offer a clue as to how partnerships can form and grow if we regard them as leadership communities. He states that the leaders must be "predisposed to the work" and are drawn to the "systems perspective." They must also create community building activities that are "intense enough and open ended enough to foster trusting relationships and to offer starting steps in applying new knowledge and skills to vital issues (Senge, 2004)."

Conclusion

The purpose of this paper is to conduct a literature review on the attributes of educational partnerships designed to create global changemakers. This literature review found information to support the idea that there needs to be a movement toward innovative change in our primary and secondary educational systems. Schools need to establish internationally focused educational partnerships in order to provide societal value in providing an education that prepares students to become solutions oriented innovative thinkers. Themes emerged in the literature outlining key attributes of growing sustainable partnerships. These themes include collaboration and connections, a need for complex systems that follow a framework, committed leadership that has expertise, forward-thinking mentality, presence of quality that evolves and creates value, engagement fostered through innovation and ideas, trust communicated through transparency and ethics, and a global vision. As there is a call to create and sustain global educational partnerships, there is a lack of guidance as to a basic structure that partners should follow to generate a high probability of success in securing and sustaining partnerships.

There seems to be an understanding that global educational partnerships create value; however, there is a gap in the literature that indicates how partners know they have created value. Although trust,

collaboration, understanding, innovation, and perspective are some attributes of sustainable educational partnerships uncovered in this literature review, more research is needed regarding the implementation of and structure of complex systems set in place at schools who are able to successfully sustain educational partnerships. This research would help school leaders make an informed decision as to whether or not entering educational partnerships would be a good fit for their school.

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2b. Educating for Sustainability

Abstracts

Submission ID: 59

Mapping the Progress of Circular Economy Integration in Portuguese Higher Education Curricula

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Abstract

The Organization for Economic Co-operation and Development recognizes the importance of incorporating circular economy (CE) principles in Higher Education Institutions (HEI) to address global challenges, equip individuals with relevant skills, promote innovation, and contribute to sustainability. By introducing CE principles into their curricula, educational institutions can encourage students to think creatively and develop solutions that to support the shift from the linear model of "take-make-use-dispose" to a circular model of resource management, that replaces the 'end-of-life' concept. Numerous studies on the integration of the circular economy have focused on the Portuguese higher education system; yet there is still a dearth of information regarding the areas in which the system needs to be improved. This research explores the HEI's current approach to CE using the Portuguese case. Specifically, it will assess the extent to which circular economy principals, approaches, models, or frameworks are presently included in the curricula second-degree cycle public HEI. Portugal was chosen as the case study because of its noteworthy advancements in sustainability-related activities for higher education and its potential to provide insightful information about how to apply circular economy principles in higher education. Thus, content analysis will be conducted using the curricular courses of each study programme previously approved and assessed by the Portuguese National Agency for Assessment and Accreditation of Higher Education. The study's major conclusions will offer relevant insights into the current integration of the circular economy into the national higher education system. Furthermore, the main research outcomes may also be used to identify areas in which the system needs improvement and to better educate students about the opportunities and challenges presented by the circular economy. A more comprehensive analysis of the research findings on the development of CE education and its role in assisting public policies in fostering thinking for a transition towards sustainability.

Submission ID: 106

Enhancing Undergraduate Learning and Community Engagement in Sustainable Development through Place-Based Education and Lab-Scale Engineering Models

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Abstract

This abstract presents an innovative approach to reinforce undergraduate understanding of sustainable development via place-based education and lab-scale engineered models.

Project 1 concentrates on the development of lab-scale models for Green Stormwater Infrastructures (GSIs). Urbanization increases impervious surfaces and therefore increased peak flows, flooding events, pollution, and sewer overflows. Constructing demonstration units like rain gardens and wetlands in the college's engineering lab provides hands-on experience and raises community awareness of sustainable stormwater management. The project enhances Water Quality, Environmental Sustainability, and Water Treatment, enriching experiences for Juniata's students.

Project 2 evaluates runoff management on Juniata's 110-acre campus, where Muddy Run Creek receives runoff from from residence halls and parking lots. Through site assessments, flood mapping, and the application of EPA Stormwater Calculator, the project identifies areas prone to runoff issues and proposes GSI solutions. A combination of green roof and rain barrels is suggested for the campus's largest building, potentially reducing over 31,000 gallons of runoff for a 1-inch design storm while also offering economic benefits via the reuse of harvested rainwater. Similarly, a bioswale is proposed for a campus parking lot to mitigate runoff discharge into the local creek, thereby safeguarding water quality in the streams. These GSI implementations not only yield direct benefits but also serve as experiential learning opportunities for students through hands-on research and project involvement.

Project 3 focuses on the water quality assessment of Muddy Run, a local stream in Huntingdon, Pennsylvania. Through comprehensive sampling and analysis, the study identifies sources of pollution and evaluates the stream's health. Significantly higher nutrient concentrations and lower DO levels ($p<0.05$) were observed as the stream emerged from underground indicating a point source discharge of nutrients in the creek. TDS and conductivity values were observed to be higher at locations near impervious surfaces with an indication of runoff from streets and parking areas. Findings indicate the impact of urbanization on water quality, emphasizing the importance of continuous monitoring and informed decision-making for watershed management. By integrating these projects into the undergraduate curriculum, students not only acquire technical skills but also develop a deeper understanding of the interconnectedness between environmental issues and sustainable development. Furthermore, the involvement of students in local projects fosters community engagement and empowers future environmental leaders to tackle pressing sustainability challenges.

This proposed abstract relates to SDG 4.7 and 13.3. It aligns closely with the conference theme, offering multifaceted approaches to educating societies and communities on addressing localized challenges.

Submission ID: 118

Advancing Sustainability Practice through Digital Learning: A Comprehensive Approach

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Abstract

The urgency to achieve Sustainable Development Goals (SDGs) by 2030, particularly in vulnerable regions like the Hindu Kush Himalayan (HKH) area, heightened by the COVID-19 pandemic, necessitates innovative strategies. The abstract outlines a comprehensive digital learning approach, focusing on two initiatives: ForHimSDG and In Our Hands.

ForHimSDG employs a hybrid learning ecosystem, combining online and in-person modalities, to enhance accessibility, flexibility, and engagement. Primarily targeting sustainability practices, including SDGs and evidence-based planning, the initiative utilizes blended learning models incorporating synchronous and asynchronous activities. Interactive content delivery mechanisms, like virtual simulations and gamification elements, augment the learning experience, fostering enhanced engagement and retention among learners.

Conversely, In Our Hands, a youth entrepreneurship program in Nepal, endeavors to cultivate a creative green economy to advance climate goals. It offers workshops, mentoring sessions, networking events, grants, and showcases. Central to this initiative are craft toolkits, providing hands-on learning experiences tailored to sustainability practices. These toolkits, offering essential materials and instructional resources, facilitate creativity and skill development among participants.

While both initiatives aim to empower individuals and communities in addressing sustainability challenges, it's notable that craft toolkits, despite their physical nature, complement digital learning methodologies within the broader program framework. Though primarily focusing on experiential learning, craft toolkits may also integrate digital elements, such as instructional videos or online resources, enhancing their alignment with the digital learning approach.

Together, through the integration of digital learning methodologies and hands-on experiences facilitated by craft toolkits, these initiatives strive to contribute significantly to the achievement of SDGs and the establishment of a sustainable future for the HKH region and beyond.

Submission ID: 134

Empowering Sustainability: The Impact of Urban Toilet Design on Environmental Education

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Abstract

Public toilets are an integral part of urban infrastructure, supporting the well-being and comfort of individuals in their daily lives. The absence of on-street toilets contributes to instances of open urination and defecation, giving rise to public health. Addressing this issue is crucial not only for maintaining hygiene but also for mitigating the associated health risks and improving the overall quality of public spaces. Providing accessible on-street toilets can play a vital role in curbing such practices and fostering a cleaner, healthier urban environment. Public toilets serve as essential infrastructure in cities, ensuring the specific needs of various demographic groups, such as women, transgenders, individuals, homeless populations, the elderly, and people with disabilities fundamental right to sanitation and enhancing their comfort while navigating public spaces.

Indeed, education plays a pivotal role in promoting the responsible use of public toilets for the sustainable environment. By raising awareness about the importance of proper toilet usage, individuals can be encouraged to maintain cleanliness, conserve resources, contributes to sustainability and a healthier public environment. Public awareness campaigns can highlight the significance of using public toilets responsibly, reducing instances of misuse, and fostering a collective sense of responsibility for communal spaces. Education becomes a powerful tool in cultivating a mindset that values and actively participates in maintaining the hygiene and sustainability of public toilet facilities.

With the rapid sprawl and urbanization of cities, the scarcity of available public toilets has become a common challenge. Balancing accessibility, convenience, and strategic placement is essential in addressing the challenges associated with the expansion of public toilet infrastructure in evolving urban landscapes. The study is been conducted in Bengaluru, leveraging secondary data analysis and focused primary surveys in specific areas. The evolution of public toilets is been analyzed from 1862 to present from Bengaluru City Corporation toilets to Swachh Bharat Mission Urban Public Toilets. By doing so, the study aims to shed light on potential gaps in current knowledge and seeks to contribute to the development of effective and well-designed public toilet facilities that cater to the specific needs of urban environments, promoting better sanitation and enhancing the overall quality of urban spaces. Certainly, overcoming challenges in public sanitation can be addressed through innovative toilet design and through educating people. By focusing on creating better designed toilets, we can enhance functionality, accessibility, ease of maintenance and sustainability. The study aims to provide design solutions and education to improve sanitation infrastructure, making it more efficient, user-friendly and sustainable.

Submission ID: 137

Investigating Factors to Improve Education in Rural Public Schools in Nepal Through the Use of Computer Technologies

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Abstract

Computer technologies continue to evolve, and new learning methodologies are emerging in developed countries. They are directly impacting the methods by which students in advanced countries learn in their educational institutions. However, there is almost no impact on how students are learning in rural areas of developing countries such as Nepal as these technologies are not being used. Significant numbers of schools in rural areas of Nepal have very limited access, or have no access, to any computers for student's learning within their classrooms.

In advanced countries educators are developing the teaching methodologies that embrace the use of computer technologies into their classrooms. In most cases this is not seen in the rural areas of Nepal, where computer teaching is mainly focused on the basics of word processing.

This study aims to investigate the important factors that affect how computer technologies have (or have not) been used in rural areas of Nepal. In our visits to three different rural areas of Nepal in the last four years, we have observed various factors that affect how this lack of adoption affects the learning and teaching of children in these rural areas. The introduction and use of computer technology have not been adopted well by schools in these rural areas. Data collected during our field trips show poor results with almost a non-existent use of computing technology. However, in the case of one school only, there was a fully-fledged attempt to integrate computer technology as a tool into the student's learning environment. The results in this school compared favourably to those in all other schools visited.

Submission ID: 161

Strengthening Teaching and Research on Sustainable Development by Co-developing and Joint-offering Courses

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Abstract

Currently, countries are not on track to meet Sustainable Development Goals (SDGs) by 2030, further exacerbated by the negative impacts of the COVID-19 pandemic. Thus, accelerated efforts and increased support are needed to achieve SDGs. The Hindu Kush Himalayan (HKH) region has eight countries, including Nepal, with such needs. Strengthening these countries' teaching and research on SDGs and evidence-based planning, policies, and practices will contribute to their sustainable transformation. Against this background, we aim to strengthen teaching and research on SDGs in the HKH region by fostering North-South and South-South cooperation. We achieve this vision by developing and realizing higher education partnerships between institutions in Germany, Thailand, and Nepal. Further, we extend this partnership with other institutions in the HKH regions, building a ForHimSDG network.

We co-developed a course on sustainability in a workshop in 2022 in Nepal. The workshop has the objective of sharing knowledge and experiences on sustainability-related curriculums among higher educational institutes in the HKH regions. During the workshop, we co-developed introductory and advanced courses on global sustainability goals and approaches to sustainability, considering the local context. The co-developed course was offered to students in Thailand and Nepal in 2023 in a hybrid mode. We shared our experiences implementing the co-developed course in a workshop in 2023. During the workshop, we also explored the possibility of transferring and adapting the co-developed course at other HKH institutions/universities. We also developed a Massive Open Online Course using the materials while offering the course.

We conducted these activities under the ForHimSDG project, funded by DAAD (German Academic Exchange Service) under the call SDG Partnerships, which is financially supported by the Federal Ministry for Economic Cooperation and Development of Germany.

Submission ID: 190

ARTE Projet: Reflective Learning through Theater for Socio-Ecological Transformation

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Abstract

Over the last 70 years, the acceleration of human impact on the planet has been so rapid, abrupt and intense that it has not given nature the time to react and absorb the impact. The paradox of today's life is that humanity is destroying what keeps it safe, demolishing the foundations of a stable climate, living in ecological debt, close to a point of "no return". Education for socio-ecological transformation is a fundamental pillar for Higher Education Institutions' role in avoiding climate collapse. The use of pedagogical strategies based on arts, particularly theatre techniques, has the potential to act as a transformative learning approach, fostering the development of different social, cognitive and personal competences in students. Theatre is expected to offer a platform to explore different perspectives and promote empathy and social awareness, through a multi and inter-disciplinary approach.

This study intends to present and discuss the implementation of an innovative pedagogical project named "ARTE project: Reflective Learning through Theater for Socio-Ecological Transformation" and its preliminary results. The project aims to promote Master students' transversal competences, the understanding and the ability to solve complex problems in sustainability transformation and climate change impact through theatrical techniques. The ARTE project was implemented in the first semester of 2023/2024 in four courses of three Master's degrees: Political Science, Administration and Public Policy and Regional and Urban Planning, in collaboration with the GrETUA (the theatre group of the UA). The partnership with this group provides theoretical and practical knowledge to the project, connecting students and teachers with national artists, and promoting cohesion within the university. It involved 27 students and 8 staff members. To gauge the project's impact, pre- and post-surveys and three final focus groups were applied to students.

The preliminary findings suggest that using theatre as a learning tool can improve students' transversal skills and increase their social awareness and involvement regarding sustainability and climate change impact. This interactive approach can lead to a more engaging and participatory educational experience. Nevertheless, the use of innovative pedagogical approaches demands additional support and articulation to be felt comfortable by the students. The overall results support the argument for incorporating creative and artistic methodologies in Higher Education pedagogical strategies. The ARTE project has the potential to be replicated in other academic settings and applied to different disciplines. Overall, theatre-based pedagogy has the potential to foster transformative learning, creativity and collaboration among Master's students, providing new ways to "Link (challenging) Futures" and contributing to SDG4.a Effective learning environments and SDG13.3. Build Knowledge and Capacity to meet Climate Change.

Keywords: *Theatre, Pedagogical Innovation, Sustainability, Climate Action, Higher Education*

Submission ID: 212

Teachers' Mindsets: Is It Relevant for Sustainability?

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Abstract

The current sustainability outlook indicates that we are still far from achieving the objectives set out in the Agenda 2030, requiring global collective and individual efforts that include a mindset shift for behavior changes. As a key element in promoting sustainability, many authors emphasize the importance of changing mindsets to reach social transformation. This approach argues that sustainability can be achieved if peoples' worldviews and mindsets concerning different spheres of life, especially regarding self-perception, connection with others, and with nature, alter to a more ecologic way of living. In other words, sustainability depends on behavior, which depends on peoples' worldviews and mindsets as deep leverage points for the necessary behavioral change. In this context, education, particularly at higher education level, can contribute to the mindset shift, through processes in which teachers play a decisive role as transformation agents. However, despite many authors have studied the subject field of the role of education on sustainability, regarding sustainability competencies development or mindset changes in student's education, fewer have done research regarding teachers' worldviews, mindsets, and related constructs.

The literature review suggests different worldviews on sustainability, including among teachers, which may affect education for sustainability and social transformation. This review aims to present an integrated literature review on the potential impact of teachers' worldviews, mindsets, and related constructs on behaviors and teaching practices while exploring their relationship with social transformation for sustainability.

Submission ID: 265

Enhancing Sustainability Learning and Curricula in Portuguese Higher Education: A Comprehensive Approach through Key Performance Indicators

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Abstract

Integrating sustainability into Higher Education Institutions (HEIs) requires a multifaceted approach across education, governance, research, operations, and outreach. Education plays a pivotal role in achieving Sustainable Development Goal (SDG) 4 for quality education, ensuring learners gain the knowledge and skills needed for sustainable development. By aligning learning and curricula with sustainability and relevant Key Performance Indicators (KPIs), HEIs can create a holistic system that meets educational goals and supports broader sustainability objectives. In Portugal, the Sustainable Campus Network (http://www.redecampussustentavel.pt) aims to establish an Observatory to assess and monitor the implementation of sustainability practices at Portuguese HEIs. While existing sustainability assessment tools at HEIs cover various KPIs, there is still a lack of understanding of those specific to learning and curricula, particularly in exploring how these indicators could be adapted and applied to the Portuguese HEIs. The study proposes a set of KPIs focusing on learning and curricula for sustainability, to support the innovative Observatory's mission in Portuguese HEIs. This Observatory represents a pioneering effort of its kind in Portugal, helping to shape governmental policies and institutional strategies for the long-term growth of Portuguese HEIs. A comprehensive literature review is underway to extract KPIs from existing sustainability assessment tools. These KPIs will be systematically categorized based on associated metrics. A methodological approach will also be proposed for organizing data on learning and curricula within the Portuguese context. The literature review is essential to shaping the proposed KPIs and informing the research framework. Accordingly, the foundation for defining the KPIs rests on the importance of reliable sources and comparable data, essential for developing a meaningful and effective Portuguese set of KPIs, representative of the national landscape. Criteria such as thematic areas or dimensions of sustainability, will guide the consistent categorization of indicators. This approach has the potential to create a standardised framework for assessing sustainability practices across Portuguese HEIs. By organising and categorising KPIs, the research aims to identify strengths and gaps current curricula and learning approaches, offering a foundation for targeted improvements. These outcomes will enrich students' educational experiences and deepen their understanding of sustainability challenges and opportunities in the context of the assessed HEIs. Recommendations for refining learning and curricula, based on the research outcomes, will guide HEIs toward a more comprehensive and effective approach to sustainability education in Portugal. The expected impact extends beyond the local context, fostering a global culture of education for sustainability in HEIs and contributing to SDG4, target 4.7.

Submission ID: 272

Eco-Conscious Education: Exploring Sustainable Alternatives for Paper-Based Practices in Architecture and Design Schools.

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Abstract

The world produces over 400 million tons of paper yearly, creating a paper waste crisis that needs urgent attention. This research aims to tackle environmental challenges by proposing sustainable alternatives to paper-based practices in architecture and design education. The primary goal is to reduce deforestation, habitat destruction, and ocean pollution while promoting environmentally friendly practices in academic settings.

The study identifies viable alternatives to paper-based practices within architecture and design schools, quantifies the environmental impact of paper production, and highlights the consequences of mismanaged paper waste. The research focuses on Tier-II cities like Hubballi in India and examines the implications of adopting alternatives to paper-based submissions in architectural education. It analyses courses from the fourth and sixth semesters at the School of Architecture, KLE Technological University.

The research applies quantitative and qualitative methods, combining faculty opinions and student feedback. Faculty insights and student perspectives provide qualitative understanding, while quantitative methods measure paper usage's environmental and economic sustainability in architectural submissions. The study's context in Hubballi, India, is a microcosm for global applicability to architectural education.

The target audience includes educators, students, and policymakers within architecture and design schools, emphasising the study's relevance in diverse academic and geographical contexts. The research is significant because it advocates for transitioning from prints to participatory methods, offering a three-fold approach (elimination, alteration, and management) to sustainable practices in architectural design studios.

The research aligns with Sustainable Development Goal (SDG) 4: Quality Education, promoting inclusive, equitable, and quality education through digital practices. It also supports SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) by reducing the carbon footprint and addressing environmental degradation associated with paper production.

In conclusion, this research advocates for a shift in architecture and design education towards sustainable alternatives. By aligning with specific SDGs, the study offers a comprehensive framework for promoting ecological responsibility, technological advancement, and pedagogical innovation in pursuing environmentally conscious architectural and design practices.

Submission ID: 289

The Impact of Business-University Collaboration on Students' Knowledge Exchange for Sustainability: Evidence from the UK

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Abstract

Knowledge exchange in higher education in an emerging area delivered through business-university collaboration, combining academic knowledge and businesses needs. Knowledge exchange can act as a vehicle for embedding sustainability in the curriculum and help address the major challenges we face as a society. Student knowledge exchange is two-way learning, i.e., for both students and businesses involved in a project. There is a need to assess the impact of student knowledge exchange on students to inform curriculum design and development for better student experience and employability in line with business needs. This research aims to measure the impact of student knowledge exchange for sustainability delivered through the business-university collaboration on students from business and built environment disciplines. The study uses two schools at Nottingham Trent University that embedded project-based learning in four courses to support student knowledge exchange for sustainability. Data was collected using surveys before and after the project took place. Surveys were based on frameworks on the sustainability competencies of students, students' skill development, students' perceptions of sustainability, students' attitudes and behaviours, and students' career readiness. Data was analysed using statistical analysis. It is found that there is a positive and significant impact on students from the knowledge exchange for sustainability in the different disciplines. The benefits and disadvantages of distinctive approaches adopted, including activities integrated into the curriculum versus extracurricular activities, bespoken versus ad-hoc projects for different organisations and the duration of students' exposure to sustainability-related topics are discussed. This study contributes to the field of higher education teaching and learning and its impact on sustainable society. Project-based learning in higher education teaching and learning sustainability can enhance student knowledge exchange.

Submission ID: 299

Sustainable Geoeducation Framework: Bridging Insights from Tokachi-Shikaoi Geopark, Japan

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Abstract

Geoeducation in geoparks serves as a cornerstone for promoting sustainable development through geological and geomorphological relic protection, geo-knowledge dissemination and economic growth. This study examined the educational sustainability of geoparks, focusing primarily on the Tokachi-Shikaoi Geopark in northern Japan. Prior to 2018, geoeducation initiatives at schools in Shikaoi demonstrated effectiveness. However, discontinuation there after necessitated efforts to revive and enhance educational outcomes. Therefore, a partnership framework was proposed by engaging stakeholders including the Tokachi-Shikaoi Geopark, universities, and local elementary/junior high/high schools. Leveraging university resources and integrating geopark-related content into e-textbooks can ensure sustainability of educational initiatives.

Moreover, this study assessed the educational model implemented at the Cuihuashan National Geopark in China, employing questionnaire and interview surveys with students and relevant informants to identify areas for improvement in the educational approach. Leveraging insights gained from the case of Tokachi-Shikaoi Geopark, recommendations are proposed for the Cuihuashan National Geopark, including the implementation of interactive learning activities, capacity building for educators, and the development of tailored educational resources to optimize its educational impact.

The findings highlight the effectiveness of geoeducation initiatives at the Tokachi-Shikaoi Geopark before 2018, followed by the need for revitalization and enhancement alongside a proposed new partnership framework. Similarly, the educational model at Cuihuashan National Geopark demonstrates efficacy, yet it requires enhancements to fully realize it's potential. Consequently, this study underscores the importance of geoeducation in driving sustainable development and proposes a partnership framework to elevate educational outcomes with geoparks.

Drawing upon the experiences and insights of the Tokachi-Shikaoi Geopark, this study presents valuable recommendations for enhancing geoeducation practices at the Cuihuashan National Geopark. Furthermore, it underscores the importance of the continuous assessment and improvement of geoeducation initiatives within geoparks. Through collaborative efforts and innovative approaches, geoparks can realize their potential as educational hubs, fostering environmental protection and sustainable development worldwide.

***Keywords**: Geopark, Geoeducation, Sustainable development, Partnership, Japan, China*

Submission ID: 312

21st Century Understanding of Sustainability: How Teaching System Thinking Can Ease the Transition

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Abstract

This note is to consider some of the key challenges of transition towards strong sustainability, based on the economic paradigm shift as a driving force. Despite the development in understanding and practice of sustainability globally, the economy based on an obsolete fragmented and mechanistic worldviews and mindsets lag significantly behind and remains mainstream, still following the "business as usual", "doom and gloom", and "less bad" track.The demonstration workshop at the conference offers participants to trail system games and discuss the best practices of education and training to develop system thinking and design skills.

In the presentation author stresses the importance of promoting the understanding of the system thinking, the circular economy, 'strong sustainability' through advanced interactive student-cantered approach to education. This work is based on the author's experience and involvement into hundreds of educational projects in various countries.

Widely spread and accepted concept of sustainable development goals helps us to focus on essential aspects and elements of sustainability. Governments, local authorities, and corporate sector have a chance to structure and prioritise their SD programs and activities. The very idea and the theme of this conference correlates with the core principles of the contemporary thinking and the mindsets which are required to understand and ensure transition towards stronger sustainability. Two seemingly departed and remoted natural areas have strong connections unseen, if the systemic and wider view is missing. The concept of SDG, although valuable, lacks a vision of the real-world natural complex nesting systems, where the larger systems sets the boundaries and defines the rules, of subsystems and their elements. These systems are full of feedbacks, resilience, and self-regulation.

Thus, mimicking nature gives us prompts and teaches towards stronger and real sustainability and long-term resilience of economic and social systems. In this concept, there is no point in having a non-effective system, and an effective system is one that is able to maintain itself. Using the analogy from the living systems approach, it should be able to adapt to changing circumstances, and to maintain homeostasis.

Contemporary economic systems are linear and open-ended, being created with thinking and mindsets which are obsolete in 21st Century. They do not fit into the limits of the biosphere. Thus, there is an urge of transition towards the circular economy as "an industrial economy that is restorative or regenerative by intention and design" (has been framed by the Ellen MacArthur Foundation 2013). System thinkers with understanding of the importance and vital features of nested nature-like systems' principles and skills to design such systems are to be trained and educated in a new manner. Future leaders and system designers have their mission to drive transition to the circular economy which is restorative by design, and which aims to keep products, components and materials at their highest utility and value.

Full Papers

Submission ID: 99

Educating on Sustainable Product Design for a Circular Use of Water: Reflections on the Results of University Design Studios for this New Scenario

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Abstract

This paper reflects on the education of designers for sustainable development, which can follow the evolution in progress in the design discipline in general. From how to design to what to design, moreover, today designing products should not only care about the interaction of the user-object, but also the user-object-environment to ensure that what is designed makes sense without compromising the critical environmental situation. The design for sustainability field has emerged to design more sustainable products following the ecodesign principles and has evolved over the years from ecodesign to design products, services, and systems for system innovations and transitions. This paper reflects on this new design scenario taking as case studies two educational experiences on design of sustainable products for circularity in the food service, through a retrospective inquiry over the concepts designed and the educational model used. There, many groups recognized water saving as an essential point where to work and where they, as designers, can intervene, so the reflection can give insights also on educating on design for a sustainable use of water. The diffusion of this education model can help future designers to focus more on innovation for freshwater saving, especially in locations affected by water scarcity.

Introduction

The design phase of the products that we buy, use and dispose, today is called into question because, as pointed out for example by Thackara (2006), 80% of the environmental impacts are decided in that stage. In a world with limited resources, precise planet boundaries and a strict safe operating space for humanity as identified by Rockström *et al.* (2009), the need to work to reach a sustainable scenario, at least at environmental level, becomes day after day more urgent and today mandatory. This scenario can also be reached by acting on the education of future generations of designers because, as the effects of climate change will become ever more visible, they will affect their daily lives and work lives. This paper wants to reflect on the education of designers for sustainable development, which can follow the evolution that is in progress in the design discipline in general. Indeed, it is passing from how to design to what to design (Sanders and Stappers, 2014), from problem solving to problem setting (Diefenthaler, 2008) and Design for Sustainability is a field of research (Ceschin & Gaziulusoy, 2016; 2020). Moreover, it is questioning the main approach that has followed until today, the human-centreapproach, over more-than-human-design approaches where the humans are at the same level as the other planet's inhabitants (Norman, 2022; Forlano, 2017).

The reflection is done through a retrospective inquiry over the concepts designed and the educational model used in two educational experiences on the design of sustainable products for the circularity in the Food Service (FS). Among the master design students involved in working on this wider brief, some focused on the design for a circular use of water, indeed they recognized water saving as an essential

point on where to work and where they, as designers, can intervene in making FS more sustainable. The process and the results can give insights on educating on 'design for a sustainable use of water' and, more broadly, on 'design for water'. Water, a fundamental resource to preserve, that is not a usual topic for designers, was taken by students unconsciously as a new agent to consider in the design process, a step that comes from the posthumanism design approach (Forlano, 2017). Moreover, the understanding of how water flows inside the product and in the professional kitchen (PK) - using a systemic design approach - helped identify the points where to intervene, to reduce its use, or to create a circular use. The design journey experienced was also a moment to increase the ecological awareness of students about the current ecological crisis, skills such as problem framing, systems thinking and future literacy - key competencies for the European sustainability competence framework (Bianchi *et al.*, 2022) -, and to understand the responsibility of design in the current environmental scenario.

The diffusion of this education model can help future product designers work more on innovation for freshwater saving, especially in locations affected by water scarcity. SDGs involved: 6.3; 6.4; 11.6; 12.2; 12.8; 13.3; 14.1.

Literature Reviews

The Evolution of Design Discipline

Sanders and Stappers yet in 2014 claimed that there was an evolution in design, from 'how to design' in 1984 to 'what to design' in 2014 and to 'design to help ensure that what is designed makes sense in the future lives of people' predicted for 2044 (Sanders and Stappers, 2014). The shift in the scope of design from problem solving to problem setting was also recognized by other authors, such as Diefenthaler (2008). Moreover, design has always considered central the interaction user-object - the human-centred design approach (Norman, 1996) -. Today, instead, design products should not only care about the user-object interaction, but also the user-object-environment to ensure that what is designed makes sense without compromising more the critical environmental situation. Recently, also Norman (2023) has expanded the concept to design for humanity. Multiple contributions are emerging over the more-than-human-center approaches, as the one by Forlano (2017) on posthumanism.

Fortunately, the inclusion of reasoning over sustainability in the design field is not new. Indeed, Design for sustainability (DfS) is becoming a sub-field in the design discipline. DfS not only means designing more sustainable products following ecodesign principles, but has evolved over the years from ecodesign to design products, services, and systems for system innovations and transitions (Ceschin & Gaziulusoy, 2016; 2020). Should education in Design follow the evolution of the Design discipline?

Educating for Sustainability

Internationally, there is a recognition of the need for Education for Sustainable Development (ESD) in recent times. According to Unesco, the lead United Nations agency on ESD in 2005-2014: "*Education for sustainable development gives learners of all ages the knowledge, skills, values and agency to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources, and inequality. It empowers learners of all ages to make informed decisions and take individual*

and collective action to change society and care for the planet" (Unesco, 2024). After the 2030 Agenda for Sustainable Development, adopted by all United Nations member states in 2015 with the definition of the seventeen Sustainable development goals (SDGs), the Unesco published the "Education for Sustainable Development: Towards achieving the SDGs (ESD for 2030)" which covers the period 2020-2030, with the definition of a toolbox focused on five priorities: advancing policy; transforming learning environments; building capacities of educators; empowering and mobilising youth; accelerating local level action (Unesco, n.d.)

Also, the European Union worked on the ESD, with the European sustainability competence framework which recognizes skills such as problem framing, systems thinking and future literacy as key competencies, willing to work on embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, acting for sustainability (Bianchi *et al.*, 2022).

A recent key pillar discovered to reach sustainable development is the adoption of a circular economy (CE). Scholars are, therefore, also reflecting on CE education, as Minguez *et al.* (2021) with the use of Life Cycle Thinking and Kirchherr & Piscicelli (2019) proposed using five principles for a CE teaching approach: interactivity, non-dogmatism, reciprocity, constructive alignment, and problem-based learning.

A sustainable development requires the development of an ecological intelligence, according to Goleman (2009), a collective intelligence required to face challenges too complex to tackle as single individuals. This skill allows humans to understand the hidden price behind every product that we buy, recognize the cost for the environment and our health, and understand the relationship among our actions and the natural world where we live. This should enter the educational programs to raise a different new generation (Goleman, 2017).

Educating for Sustainability in Design

Badalucco (2017, p.42) reasoning over the education of designers insisted on the need to educate to understand the sense of the design action, to question why they are designing, to construct a sense of responsibility and critical thinking, to manage the innovation processes correctly using the tools ethically, creating effective solutions for responsible innovation that is attentive to social needs. In a contribution questioning how will be the design education in 2030, Collina (2020) highlighted that today *"…we are obliged, both individually and collectively, to turn our gaze "beyond", towards the future: towards the future of thousands of young people who will make design their profession and towards the future of our planet that will be partly shaped by their planning"* (Collina, 2020, p.21).

More recently, Tironi *et al.* (2023), arguing for the need for a critical review of design education, proposed the Planet-Oriented Design as a new ethical transition in design education. Vezzoli *et al.* (2023), who worked in DfS for many years (Vezzoli and Manzini, 2007), for a 2023 design conference, recognized these diverse topics - circular product development, sustainable product-service systems, craft and aesthetics, more-than-human design, and the roles of designers in societal, policy, and stakeholder contexts - as trajectories in the evolution of the DfS. DfS, in the years, has become a subfield in the design discipline, and it not only means designing more sustainable products following the ecodesign principles, but evolved over the years from ecodesign to design products, services, and systems for spatial-social and socio-

techinal innovations and transitions (Ceschin & Gaziulusoy, 2016; 2020). In the first contributions over DfS Lanzavecchia (2004) recognized the ecodesign requirements for product design and Vezzoli and Manzini (2007) had already identified the enlargement of the scope and field of action, from selection of materials with low environmental impact to product life cycle design (ecodesign), design for eco-efficient system and to design for social equity and cohesion, also identifying multiple environmental requirements to follow in product design. Bhamra *et al.* (2013), linking sustainability potential and level of innovation, identified system innovation (a radical and strategic approach that involves many stakeholders as companies, customers, communities and government) with the higher level of both, passing from the middle steps of improvement (small modifications), redesign (considers the whole life-cycle), new concepts (considering innovative ways to reach the function required).

Along DfS main research line, different subfields have emerged in design. The involvement of systems thinking in the design process resulted in Systemic Design (SD) (Jones, 2018). SD evolved in many different approaches, and one of particular interest for the DfS is the approach to ecological design theorized by Bistagnino (2011) (SDB). When working on systems and innovation is fundamental to frame the current situation to understand where to intervene (Meadows, 2011). Also, Jones & Van Ael (2022), in framing the methodology and toolkit of SD for system change designers, dedicated three of the seven steps to the system assessment before going to the more intervention stages: framing the system; listening to the system; understanding the system. One of the tools that SDB is providing is the Holistic Diagnosis (Battistoni *et al.*, 2019) applied mainly to anthropic activities, where a step - HD1 - is to understand the metabolism with flows of resources used (energy, water, people, etc.) and another step - HD2 - is related to the context/territory/ecosystem where the activity is nested.

The spreading of the Circular Economy (CE) worldwide has also impacted the design discipline. This concept in design has produced the 'circular design' research line and the definition of multiple 'design for X' strategies to achieve a CE, as the review by Sassanelli *et al.* (2020). Moreover, some approaches have been born in design practices that evolved from human-centred to life-centric design, adding environmental and ethical responsibility (Borthwick *et al.*, 2022), or design for humanity, as the most recent book by Norman (2023). This wave will consider the planet's needs at the top level as the human needs at the start of product design process. Considering this framework, can education for DfS a subfield of ESD?

Design & Sustainability in the Food Service

The research presented in this paper considers a specific context of application, the Food Service (FS), a sector where the author is concentrating the research in the last years. FS is the part of the food value chain where a meal is prepared and served. According to the Farm to Fork strategy (EU, 2020) all the stages of the food chain should have a neutral or positive climate and environmental impact to accelerate the transition to a sustainable food system, and FS, as part of this system, should contribute, even if food production is the most impactful stage (Baldwin *et al.*, 2011; Mistretta *et al.*, 2019).

Currently, design for the FS means mainly or interior design or designing the tools that are needed - to prepare and serve a meal - without the right consideration over the sustainability of this sector. If the PK of FS activities are the focus, they are complex environments with many operations performed by workers

with or without tools, transforming food involving energy, water, and producing waste (Battistoni, 2023 b). According to Subramanian *et al.* (2021) collecting data on foodwaste-energy-wateremission nexus aspects in FS is very difficult, however, it is a resource-consuming sector, for example, the study by Pacific Insititute (n.d.), indicates the use of 37,5 liters (9,91 gallons) of water per meal a day in a restaurant in 2000.

In this sector, dematerialization is impossible. We can reduce the number of kitchens or share them among FS (e.g. ghost kitchens), but we need to continue to design and produce the products to process and cook food, at least until the moment that the food as we know it today will exist, and will be not only food pills. Also, because FS for the public sector is a social necessity in the case that it is cooking for the people that cannot do it, as in elementary schools or even more in hospitals. An urgent action is to transform and adapt them to the changing conditions that will happen in not so far times, facing problems such as the changes in energy supply, water scarcity, digitalization, the increasing number of people to feed, growing numbers of older people, correlations among food and health, changing in the diet (increasing of vegetarians, ..), and more.

Methodology

This paper reflects on the education for a sustainable development in the design field. It is carried out by taking as case studies two educational experiences, where master design students of an Italian university were involved in working on a wide brief: the design of sustainable products for the circularity in the FS.

The two experiences, where the author was the main tutor, were (see table 1):

- the “product design 1” studio of the master course in product design, with a duration of one semester, where students had to design sustainable electronic equipment, half of the class for the FS sector while the other half for the health sector;
- the “Circular food service” workshop of one week on the design products/services for a circular FS sector.

The reflection is done through a retrospective inquiry over the concepts designed and the educational model used. In particular, the courses follow a specific methodology (Battistoni *et al.*, 2023) not always perfectly declared to students, considering a first phase of research to discover and define problems, followed by a second phase of product development for the solution find, developing and delivering the concepts. The phases were not linear but were considering moments of going back and forward. Moreover, the methodology was merging human-center principles with ecodesign ones - the consideration of environmental requirements in the design process (Vezzoli & Manzini, 2007; Lanzavecchia, 2004) - and Systemic Design (Bistagnino, 2011; Battistoni *et al.,* 2019). A constructivist pedagogical approach was followed, using learning-by-doing with continuous open discussions teacherstudents. These moments were facilitated by the use of visualisations as systems maps and sketches and technical drawings.

Both the experiences involved the collaboration of a leading company in the production of equipment for the FS in order to receive feedback from them over the FS sector and the solutions proposed.

Table 1. Summary of the characteristics of the two educational experiences

Experience	What	Where	When	Who		Collaboration
				Practitioners	Tutor	
1	"Product design 1" studio	Master course in product design	October 2022 - February 2023	20 students of the 1° year master students	1 professor in product design, 1 professor in eco & systemic design, 1 assistant in product design	Two moments of comparison with the industry (half and final)
2	"Circular food service system" workshop	Master course in product design	5 consequent days in June 2023	18 students of the 2° year of the master in product design	1 professor in design, 1 assistant in product design collaborating with the industry	Two specific moments of comparison with the industry (first day and final day)

Results and Discussion

The following subchapters report the two educational moments and their results. The students were always free to choose the FS context on where to work (restaurants, bars, canteen, etc.). Many of them decided to work in a context where they had a past working experience, or at least one per group.

Design Studio of the Master Course in Product Design

In this design studio, the first of the master course in product design, half of the class (20 students) received the brief to design electronic equipment for the FS. They followed a first theoretical class of 3 hours on DfS, then they were divided into working groups. They had to conduct the first research phase in autonomy for the identification of a macroproblem divided in sub-problems related to the unsustainability of the FS sector chosen, being free to choose the problems to solve, but afterwards, they were forced to follow the environmental requirements for the design of the new product, considering the life cycle, mainly focusing on maintenance and the end of life.

The first problems that students presented without confrontation with teachers were problems that are commonly discussed during the public debate on food and environmental problems (such as food waste creation and water use). Some of them were coming from their direct observation in past experiences in the sectors, such as the oil disposal in food trucks or the food degradation in catering services. After confrontations with teachers and also a moment of direct discussion with the company, they arrived at the definition of more complex and articulated problems and a consequent design solution. See results in tab.2. Along with the common files of presentation of a design product (technical drawings), they also created a "sustainability patent" to fill with the environmental requirements followed, highlighting how they eased the regular maintenance, as the substitution of a component, and the end of life.

Table 2. The results of the Design studio in product design

Published in Battistoni *et al.* (2023)				
Sn.	**Group**	**Context**	**Final Problem Identified**	**Final Solution Identified**
1	Restaurants	Degradation of food and food waste in restaurants	Food degradation in fridges	A smart box to measure the pH of food preserved in fridges and indicate the level of degradation
2	Food Trucks	Great use of oil and its disposal in food trucks	Excessive use of oil during frying and disposal	A smart fryer to reduce oil use and transform exhausted oil into biodiesel
3	Restaurants	Dispersion of heat in restaurants	Heat dispersion when ovens are switched off	A device to recover dispersed heat and use it for heating water
4	Catering	Temperature decreasing during catering service	Possible food degradation during food transport	A smart box to preserve hot temperatures during food transport
5	Restaurants	Great quantity of water used in pre-washing	Excessive water use during pre-washing	A smart device to reduce water usage while scraping food from dishes and trays
6	Restaurants	Waste of water and heat during pasta cooking in restaurants	High water and heat wastage in pasta cooking	A smart pasta cooker to use less water and recover heat from waste water

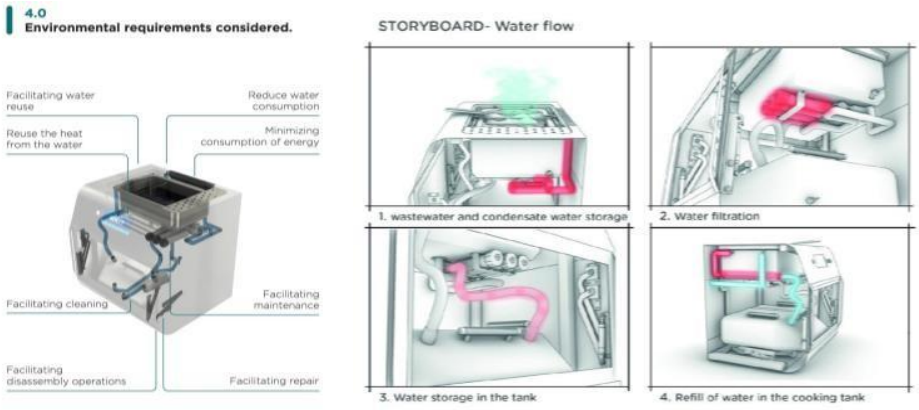

Figure 1. Examples of product design concept by group 6. Students: Abbattista, Brandola, Schembari. Rights reserved to Università Iuav di Venezia.

It was interesting to notice that some students recognized water saving as an essential point on where to work and where they, as designers, can intervene in making FS more sustainable. Indeed, two groups (5 and 6) worked on the design for a more sustainable use of water in equipment: a pasta cooker that recycles water internally and a device to reduce the use of water in pre-scraping. Another group worked on using less energy to heat water, recovering the heat from oven.

Workshop “Circular Food Service System”

This workshop of one week involved students of the master in product design that have completed at least the first year. These 18 students received the brief to design products or services for a circular FS sector. The first day they had the opportunity to visit the showroom of the industry involved in the work with a Q&A session with some chefs and the manager of the design department. The second day, in the morning they followed a theoretical class of three hours on DfS. In the afternoon there was a practical brainstorming exercise that forced them to reflect over the life cycle of FS equipment with the creation of a map on a big paper sheet with post-it (see fig. 2). It was facilitated by the teacher following a previous outline published in Battistoni (2023 a). The third day and the fourth day they performed the design process with continuous moments of reflections with the teacher, that forced them also to reflect on the interaction of the products with the resources used in the use phase, as food, food waste, energy, water …On the fifth day they finished the communication material and presented the results to the teacher and the company.

Figure 2. The results of the brainstorming over the life cycle of equipment

Also, in this case, some students recognized saving water as an essential point on where to work and where they, as designers, can intervene in making FS more sustainable. Indeed, three groups (3, 4 and 5), see tab. 3, worked on the design for saving water: a product to degrease water to reuse it in kitchens, a module for hydroponic harvesting to use the water discarded from the vegetables washing. Also, in this case a group worked on saving energy to heat water thanks to a system of tubes that enter in the hoods to exploit the heat. These groups studied the water fluxes of water in the kitchen within the process, see fig. 2.

Table 3. The results of the workshop on FS circularity

Group	Context	Problem Identified	Solution Identified
1 - Generic	Food waste generated in food processing	Food waste generated during processing	A component for the desk to manage food waste with compost generation and an app to deliver compost.
2 - Pizzeria	High price of flour + great flour waste	Excess flour waste during pizza dough preparation	A component added to the desk to recover excess flour.
3 - Generic	Great use of wastewater in kitchens	Excessive wastewater in kitchens	A component with a degreaser and filter to enable water reuse in a closed loop system.
4 - Restaurant	Great use of water in food cultivation + waste in cleaning	Excessive water use for cultivation and cleaning	A hydroponic module using water discarded after vegetable washing.
5 - Generic	High temperature in kitchens + great use of water in cooking	High heat and water usage during cooking processes	A tube system in the hood to use heat and provide water for cooking.
6 - Generic	Great quantity of electronic waste	High electronic waste from kitchen appliances	Selling products (e.G, ovens) on loan to support maintenance and recovery of spare parts.

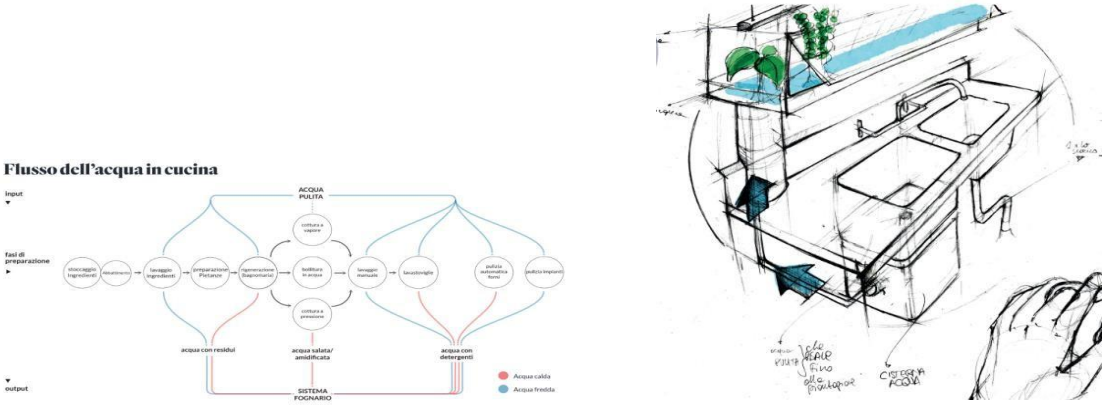

Figure 3. Examples of study of water fluxes in the kitchen

Discussion Over the Education Experiences

The two experiences were performed by practitioners with different timing, levels of experience and awareness on sustainability and circularity, as shown in tab. 4. They also reported two slightly different levels of approaches to DfS. In the design studio the focus was on the nano level of the equipment in a PK, and in this case, the students focused more on the sustainability of products itself. In the second one, the workshop, thanks to the brainstorming activity and a different level of maturity on product design that required less effort on the product design concepts - end of second year rather than beginning of first year of master - the students were able to consider more the relationship between the equipment and

the rest of the products and processes that happen in a PK. In this case, their level of intervention can be considered slightly more than nano-level (referring to Battistoni, 2023) but they arrived only to draft concepts, due to the time constraints, concentrating less on the product life cycle. In both cases students were forced to reason on having outcomes at product level, not only at changing materials (that in the FS is difficult due to hygiene constraints), but on working on product innovation through improving the existing ones or developing completely new products. During the tutoring, they were also sustained to think not only about the product life cycle, but to think about their interaction with resources with the potential to close loops - or opening to other processes - of resources also during the product use and not only at the end of the life cycle. Thanks to this aspect, there was some group that tried to create connections for example among the heat dispersed and the need to have hot water.

Table 4. A comparison of the two educational experiences

Experience	What	Who	Time	Experience on Design Process	Experience on Design for Sustainability and Circularity	Level of Approach to DFS	Level of Intervention
1 - "Product Design 1" Studio	20 students of the 1st-year master students	5 months	Low	Low	Product level	Nano level (equipment)	
2 - "Circular Food Service System" Workshop	18 students of the 2nd-year master in product design	1 week	Medium	Low	Product level	More than nano level (equipment-kitchen)	

The design journey, in both cases, was a moment to improve the students' skills such as problem framing, systems thinking and future literacy - key competences in European sustainability competence framework - It was also a moment to increase the ecological awareness of students about current ecological crisis and to understand the responsibility of design in this scenario.

The fact that many groups decided to work on water saving can give insights also on educating on 'design for a sustainable use of water' and more broadly on 'design for water'. For them, a phase that resulted important was the understanding of the system, and how water flows in the PK. A SD approach and the use of its tools, as the HD to delineate the water fluxes, was helpful for the students, to individuate the problems. Because, in this case, they didn't need to start the design process as it is classically performed: starting from problems individuated by market trends or related to the use of the product by humans. Indeed, the water is not taken into consideration by kitchen operators until they receive an expensive water bill. Water was taken by students as a new agent to consider in the design process, a step that comes from the posthumanism design approach (Forlano, 2017). Moreover, the understanding of how water flows inside the product and in the PK helped identify the points where to intervene, to reduce its use, or to create a circular use. An open question is to understand how much time dedicate to this phase, because it is an additional step to perform in the design process to enable the design for this new scenario, but it makes it longer, and usually time constraints in design studios should be respected, also because the results - a new product - should be also well deepened in details and well communicated. In reality, the approach at nano level used by the students contains reflections and relationships with the macro

level - the system one -, but actually it was made without a real awareness of this type of action. Moreover, the move from one level to another one was made multiple times. The relationship between the nano and macro level can be seen in fig. 4. It seems that the better solution is to guide the students through a design process that is a mix of the two different educational experiences had: giving time both on the inclusion of systems thinking aspects, to delineate the sustainable goals of products, the sense making, and to focus also on the environmental requirements of the products itself, for a life cycle thinking approach to better the 'how to do' phase.

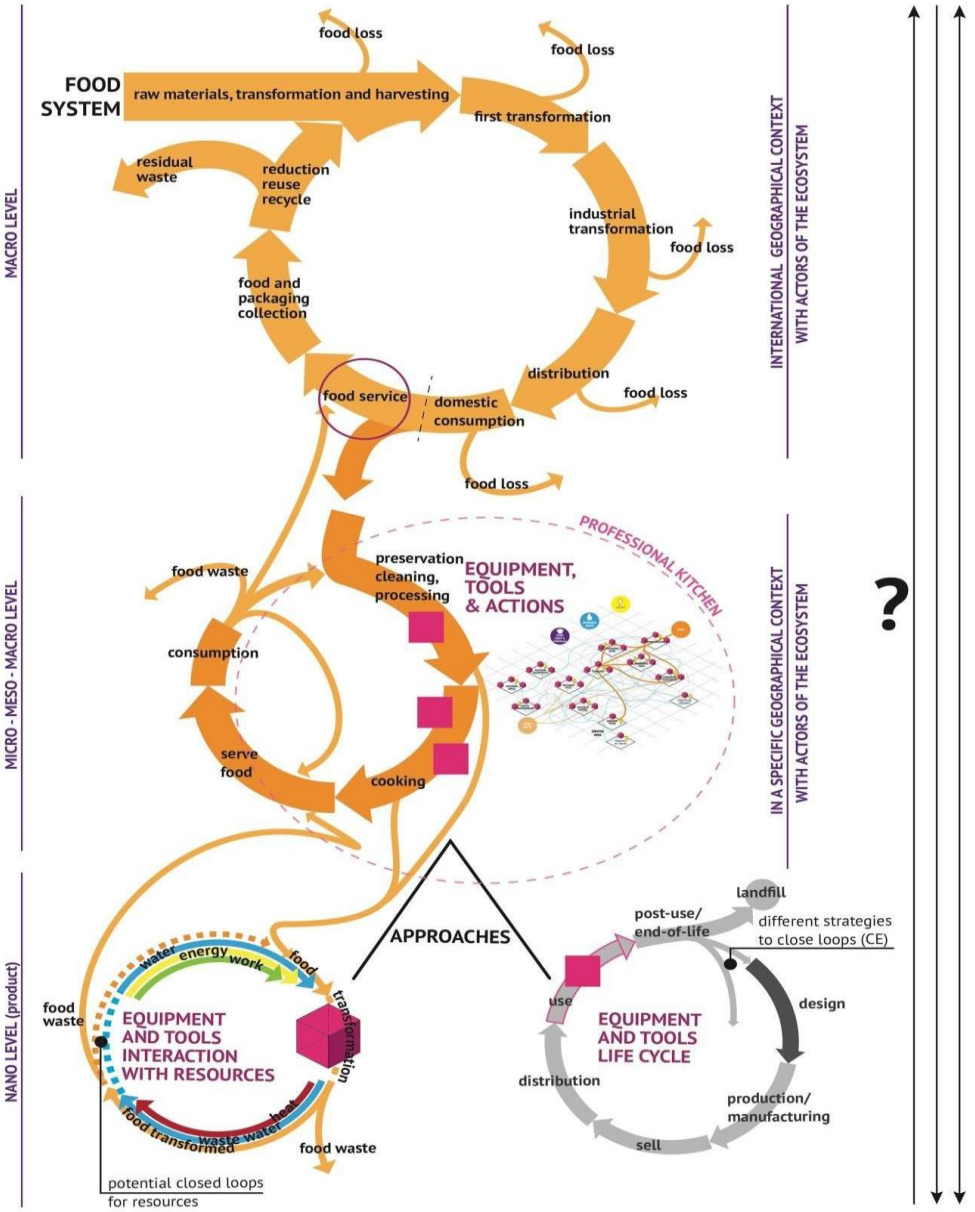

Figure 4. From nano to macro level approach that can be used in design for the FS. The macro level starts from the value chain of the CE for food (Fassio & Tecco, 2018).

Conclusion

The results of the design process and the visualisations that the students have delivered tell about the impact of these educational experiences, even if the changes in the students, before and after the courses, were not quantified at the end of the process. These experiences had an impact on the education of students on giving the skills to address interconnected global challenges, make informed decisions and take individual and collective action to change society and care for the planet, as the Unesco wants for future generations. Moreover, they were moments to increase the ecological awareness of students about the current ecological crisis, and providing skills such as problem framing, systems thinking and future literacy - key competencies for the European sustainability competence framework. Considering this, education for DfS can be proposed as a subfield of ESD.

The process and the results give insights also on educating on 'design for a sustainable use of water' and, more broadly, on 'design for water'. It is not a usual topic for designers, but it can become thanks to the new design movement which tends to consider new agents in the design process, a step that comes from the posthumanism design approach (Forlano, 2017). In this case, a systemic approach was important to use to understand how water flows inside the product and in the PK to identify the points where to intervene, to reduce its use, or to create a circular use. It can be an example for design that want to consider the future of our planet, where there is the need to understand the sense of the design action, to question why we are designing, to construct a sense of responsibility and critical thinking, to finally develop an ecological intelligence (Goleman) understanding the relationship among our actions and the natural world where we live.

The diffusion of this education model, in particular the one on the topic of water saving, can help future product designers to work more on innovation for freshwater saving, especially in locations affected by water scarcity. Indeed, water is considered the gold of the 21st Century (ICWRGC, n.d.) and there are studies that warn on the future increase in the demand of freshwater (OECD, 2012), contributing to water scarcity caused also by climate change (UN water, n.d.), causing an increase of water scarcity in more countries in 2050 (Baggio, Qadir & Smakhtin, 2021).

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Trainers' Knowingness, Attitude, and Practice of Design for Sustainability: Perspectives from Special Technical and Vocational Education and Training Institutions, Kenya

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Abstract

Design for Sustainability (DfS) comprises multiple approaches geared toward sustainable production and consumption. Leather and fashion production and consumption are unsustainable. The phenomenon calls for a paradigm shift, especially in technology education. The next generation of designers must be educated in the first years of design education about sustainability so that they can grow with the idea of designing not just one generation of products. The shift can only be achieved by DfS oriented educators. Issues on disability are increasingly gaining attention in public and policy documents but not in research. Persons living with disabilities (PLWDs) constitute 1.3 billion (16%) of the world population and 80% of them reside in low-income countries such as Kenya. Globally, Technical and Vocational Education and Training (TVET) is key to empowering adolescents and youth living with disabilities. There is a dearth of research on TVET in Africa, especially the special TVET institutions, which are established to serve PLWD. The special TVET institutions have limitations concerning the trainers and the curriculum. Some trainers in special TVET institutions are not professionally trained in the courses that they teach, such as fashion design and clothing/garment making technology and tannery and leather technology. Most of the curricula are outdated and students are not placed for industrial attachment. Thus, both the trainers and curricula may not be abreast with the global discourse on DfS. The study was conducted in Kenya's three special TVET institutions. The objectives of the special TVET fashion design and clothing/garment making technology and tannery and leather work technology curricula include among others to empower trainees to practice environmentallyconscious production. All the trainers have undergone formal training: from Diploma to Masters degree. The courses incorporate DfS in fabric colouration, garment cutting and making, workshop organization and management, material knowledge, and safety and hygiene subjects. The courses thus align with economic, social, and environmental sustainability. The respondents demonstrate an in-depth understanding of DfS and its benefits: environmental, economic, technological, and social. The trainers adopt diverse strategies to incorporate DfS in teaching, thereby encourage and guide the trainees to construct sustainable fashion products, soft furnishings, and coloured/decorated fabrics. Adopting DfS poses institutional, consumer, and financial challenges to the department. However, the conundrums are outweighed by the benefits accrued in the trainees' sustainable projects. DfS-oriented trainers and trainees are critical in contributing to Kenya's fashion and leather industry's "greening" and global competitiveness. Both parties are game-changers by promoting DfS. A capacity building workshop and a DfS manual for the trainers would enhance their skill-sets, knowingness, attitude, and value concerning DfS. The introduction of a 'Design for Sustainability' theorycum-studio unit is crucial. This study is aligned with the United Nations *Sustainable Development Goals,* 1, 2, 3, 4, 8, 9, 12, 15, and 16.

Keywords: *Attitude, Design for sustainability, Knowingness, Practice, Trainers*

Introduction

Issues on disability are increasingly gaining attention in public and policy documents (Education subSaharan Africa [ESSA], 2021) but not in research. Persons living with disabilities (PLWDs) constitute 1.3 billion (16%) of the world population and 80% of them reside in low-income countries (World Health Organization [WHO], 2023) such as Kenya. The youth (15 to 24 years) comprise slightly more than 20% of the total population in Africa (United Nations Youth Year, n.d), and includes those living with disabilities, some of who are enrolled in special technical and vocational education and training (TVET) institutions to pursue diverse courses. A minority of Kenyans (4.6%) experience some form of disability, mostly visual, hearing, physical, and mental (Sichari, 2016). PLWDs live as an invisible minority. However, with appropriate support adolescents and youth living with disabilities can develop into adults who lead contributing and satisfying lives in the community (Simmons, 2017), specifically through access to tertiary level education in fashion design and leather technology courses.

There is a dearth of research on TVET in Africa, especially concerning special TVET institutions (ESSA, 2021) which are specifically established to serve PLWDs. TVET is key to expanding opportunities for youth living with disabilities by empowering them with skills and knowledge to be self-reliant, and for social integration and self-esteem. Globally, factors inhibiting the enrolment/participation of youth with disabilities in TVET-related courses are curricula-related, the nature of the individual's disabilities, socio-cultural, and institutional policies (ILO, 2021). TVET training offers limited subject options (mainly dressmaking, leatherwork, hairdressing, poultry, agriculture, and carpentry) (KNHRC, 2015). Tailoring and dressmaking was the third (20.5%) most enrolled course in special TVETs in Nyandarua and Murang'a counties in Kenya. On the contrary, although the courses were relevant to the labour market, the trainees exited without the skills due to outdated curriculum, lack of industrial attachment, not taking the trade test, and inadequate, obsolete, and un-adapted equipment (Githaga, 2014).

The next generation of designers must be educated in the first years of design education about sustainability so that they can grow with the idea of designing not just one generation of products (Vezzoli *et al.,* 2022). Sustainability implies a multi-disciplinary model comprising various dynamic and inter-dependent elements: social, consumer, design, economic, environmental, innovation, technological, business models, marketing, raw materials, transparency (Gardetti, 2019) as well as cultural (Yang and Lupo, 2019), and such concepts as upcycling, zero-waste design, and disassembly (Vezzoli *et al.,* 2022). Design for Sustainability (DfS) is a whole system approach that considers the overall impact of designs. DfS is a multi-disciplinary and inter-disciplinary approach that can be applied in all fields including fashion, industrial, and product design among others. DfS incorporates the following principles: thinking in systems, dematerialization, renewable/natural materials, and cradle-to-cradle (Manzini, n.d).

Chen *et al.* (2022) adopted knowingness rather than knowledge. The former is regarded as recognition of the fundamentals of sustainable development (SD). Knowingness is similar to awareness, for it probes individuals' wakefulness and perceptions. The capacity building of teachers is crucial if real transformation is to take place (Pavlova, 2023), such as adoption of DfS in TVET curriculum. Some trainers in special TVETs are not professionally trained in the courses that they teach (Githaga, 2014), thus may be unaware of the global discourse on DfS.

Problem-solving is the central theme of Technology Education (TE). It is incumbent of TE teachers to constantly subject their learners to be in the habit of technologically solving the problems of their indigenous community (Mapotse, 2023) such as fashion's and leather's unsustainable production and consumption. Engaging students in real-life projects with real stakeholders/end-users of products and services, effectively aligns educational delivery with the professional practice (Moalosi *et al.,* 2012), enabling seamless entry to the labour market.

Leather is one of the most widely traded commodities globally. The demand for leather and leather products (footwear, fine leather, handbags, and auto upholstery) surpasses the supply. Effluents produced by tanneries have a significant negative impact on the environment and human health. Tanning is also a highly energy-consuming process. Consumers in developed countries especially are pushing for an acceleration of the 'green' leather industry (adoption of sustainable, clean technologies) and are willing to pay a premium for 'green' leather. The Government of Kenya (GoK) is in the process of establishing a leather industrial park in Machakos County aimed at accelerating the industry's development for socio-economic empowerment (World Bank Group [WBG], 2015). The industry will require more DfS-oriented and well-trained graduates especially from special TVET institutions to 'green' Kenya's industry and enhance its global competitiveness.

The global fashion industry is a highly significant economic player. Nonetheless, it is highly energy-consuming, polluting, and wasteful, occasioned by fast fashion. Despite modest progress, fashion has not yet taken its environmental responsibilities seriously (Vezzoli *et al.*, 2022). Although most textile solid waste originates from household sources, waste textiles also arise during garment manufacture. The waste includes cut pieces of fabrics (constituting 20% of the industry's waste), and rejected pants, shirts, and t-shirts among others (Saha, 2014; Vezzoli *et al.*, 2022). The fashion industry is transitioning toward sustainable/eco/green/slow fashion. The term 'slow' was coined by Dr. Kate Fletcher, creating an international movement in fashion from "quantity to quality." 'Slow' is an approach in which designers, buyers, retailers, and consumers are more aware of the impacts of products on workers, communities, and ecosystems (Craft Alliance, 2012).

There is a dearth of research on TVET in Africa, especially the special TVET institutions. Additionally, no research has been conducted in Kenya concerning the knowingness, attitude, and skills/practice of special TVET trainers concerning DfS, especially considering all the six content dimensions: environmental, social-ethical, cultural, technical, political, and economic sustainability. The special TVET institutions are challenged because most of the curricula are outdated and students are not placed for industrial attachment. Of concern is that some trainers in special TVET institutions are not professionally trained in the courses that they teach, such as fashion design and clothing/garment making technology and tannery and leather technology, thus they may not be abreast with the global discourse on DfS. Thereby they fail to impart the trainees with the same, denying the trainees the opportunity to critically engage with DfS. The problem persists despite the emphasis by scholars to inculcate sustainability principles to design trainees from their early years of study. Typically, studies on sustainability delve on the environmental dimension only. There is no known study conducted to probe the incorporation of DfS in special TVET curricula for fashion design and clothing/garment making technology and tannery and leatherwork

technology. There is need for a study focusing on trainers' knowingness, attitude, and practice within the broader context of DfS. Therefore, the study aimed to: evaluate how special TVETs' fashion design and dressmaking/clothing technology and tannery and leatherwork technology curricula incorporate DfS; and assess trainers' knowingness, attitude, and practice about DfS.

This paper fills the gap on the dearth of research on TVET in Africa, especially the special TVET. This study is particularly aligned with UN *SDGs,* 4: Ensure inclusive education and equitable quality education and promote lifelong learning opportunities for all, as well as 1, 2, 3, 8, 9, 12, 15, and 16.

DfS-oriented trainers shall impart and empower the young PLWDs TVET trainees to competently participate in the global discourse, thereby contribute to Kenya's fashion and leather industries' 'greening' and global competitiveness. The outcome of this study shall foster curriculum development and innovative approaches towards DfS adopting socio-cultural, economic, environmental, technical, ethical, and political sustainability.

Literature Reviews

The Fashion and Leather Industry and Sustainability

The high demand for leather is occasioned by the rapid population growth, particularly within younger population cohorts, and rapidly increasing disposable income. The industry offers an important opportunity for Kenya's industrialization and diversification of exports in achieving *Kenya Vision 2030,* and provides employment in both the formal and informal (*Jua Kali*) sectors. Kenya exports leather bags, travelware, and corporate items. African countries, including Kenya, remain marginal players in the leather industry, accounting for 3.3% of world leather value addition. Leather producers face challenges of lack of training, awareness of design trends, designers, and government support among other concerns (WBG, 2015). The issues require a paradigm shift in training leather designers who engage in value addition while practising DfS. Globally, the leather industry is embracing sustainability/'greening'. Kenya's Alpharama Tanneries is Africa's only tannery that is certified under the environmental sustainability certification regime, the Leather Working Group (LWG) and it employs leather traceability (a sustainability concept). Certification would help increase the quality of leather and enhance sustainability initiatives. Professional certification programmes are critical for training workers in production from conception to finishing, as well as quality management, thus fostering process efficiency and supply capacity (WBG, 2015).

Fashion designers have created a distance/barrier between themselves and their users. The majority approach fashion in an inward-looking practice for oneself: self-expression, aesthetic choices, and economic factors (Whitty, 2021), which leads to significantly high dissatisfaction with fashion products in the market, which is unsustainable. Fashion designers must urgently adopt the problemsolving and externally-driven approach: design for others' needs, driven by equity-led research, usercentred, and experiential approach (Whitty, 2021), concepts aligned with DfS. Adherence to the 'waste hierarchy': reduce–reuse–recycle-prevention is critical in the management of waste. The latter is of higher priority than the 3Rs (Ceschin and Gaziulusoy, 2020).

Design for Sustainability (DfS)

Ceschin and Gaziulusoy (2020) explore DfS from various perspectives including eco-design, emotionally durable design (EDD)/design for product attachment *(DfPA)*, Design for sustainable consumption behaviour (DfSB), biomimicry (BM), Product-service systems (PSS), Design for the Base of the Pyramid (DfBoP), and the knowledge and know-how required to apply various DfS approaches. Durability/longevity, be it emotional, physical, or stylistic extends the use/lifetime of apparel (Casto and DeLong, 2019) thus promoting sustainability. Universal design (UD) calls for inclusion of persons with special needs to meet their needs and preferences.

Special TVET Institutions

The TVETs' management and National Council for Persons with Disabilities (NCPWD) have not conducted market surveys for the courses. Further, the latter did not participate in curriculum development (Githaga, 2014). The TVET training is not adapted to the PLWDs' skills, interests, and abilities; and is irrelevant and unmarketable in an evolving technological labour market needs and jobs (ILO/IAPP, 2009; KNHRC, 2015) thus occasioning high unemployment among graduates (ILO, 2021). If trainers are unaware of DfS, then the graduates- potential industry change agents, will not be responsive designers.

Nexus of TVET Trainers and DfS

The past two decades have witnessed increasing recognition and political agreement that education is a major agent to transform the current society into a more sustainable, equitable, and socially just one. UNESCO's Education for Sustainable Development (ESD) is not only one of the 17 UN Sustainable Development Goals (SDGs), but is also a means to reach other SDGs. ESD encompasses the development of adequate/relevant knowledge, right attitudes, and proficient skills. To help learners prepare for the uncertainty of the future, they should be imparted with the relevant knowledge. Male and female students gave more credit to the social and environmental domains of sustainability respectively (Chen *et al.,* 2022). According to Abdelgalil (2013), the outcomes of the change project: Education for Sustainable Development (ESD) aligned with sustainable development include, created awareness among the students, re-oriented postgraduate degree scientific research plan, integrated sustainability in some course contents, and introduced new sustainability-oriented courses. Orangi's (2014) study revealed that the academic staff members in TVETs were professionally qualified. Nonetheless, they needed to upgrade their technical skills through advanced training in Diploma, Bachelors, and Masters in fashion design, entrepreneurship, information communication technology, and machine maintenance.

Undergraduate programmes in fashion and textile design have a responsibility to prepare their graduates for an ever-changing industry (Lantry, 2015), that is practically shifting toward DfS. The same would apply to TVET courses. Creative students can be self-employed, innovative, and invent things that could technologically solve the problems of their community of nations (Mapotse, 2023). Special TVET institutions' graduates get employed. For instance, a graduate of knitting is employed in a Nakuru-based industry, and another from beauty and hairdressing is an instructor in a vocational rehabilitation and training centre (Githaga, 2014). The purpose of teaching TE is to equip learners with knowledge, skills, attitudes, and values that will be needed to sustain the creative economy, and sustainable societies

(Mapotse, 2023). According to Njeru (2016) fashion design undergraduate students employ sustainability concepts in their course projects mainly through the lecturers' encouragement, interaction, discussion, consultation, and demonstration. Sustainable techniques adopted include restyle fashion products and construct reversible apparel and accessories. Special TVET trainers thus require extensive knowledge, skills, values, and positive attitude regarding DfS as they play a crucial role in the innovative learning process.

Methodology

A descriptive survey research design was adopted. The study was conducted in Kenya, among three special TVET institutes, namely Karen Technical Training Institute for the Deaf (KTTID), Machakos Technical Training Institute for the Deaf (MTTID), and St. Joseph Institute for the Deaf (SJID). The researchers were unable to reach trainers in Sikri Technical Institute for Deaf and Blind in Oyugis. Data were collected from the trainers/tutors, employing a semi-structured questionnaire. Thematic analysis and descriptive statistical techniques comprising frequencies and percentages were employed. The findings are presented in graphical format, and narratives. The participants were assured of anonymity and confidentiality of their responses.

Results and Discussion

Trainers of KTTID, MTTID, and SJID numbering 7, 8, and 5 respectively participated in the study totalling 20. The institutions are respectively located in Nairobi, Machakos, and Siaya counties in Kenya. These institutions were established by the GoK as TVET centres to serve learners with special needs/living with disabilities.

The courses are variously named as Fashion design and clothing technology, tannery and leather work technology, and fashion design and garment making technology whose examining bodies include Kenya National Examination Council (KNEC), National Industrial Training Authority (NITA), and Competency-Based Education and Training (CBET).

Respondents' and Institutions' Demographic Characteristics

Table 1: Respondents and institutions by demographic characteristics

Length of programme	**KTTID**	**MTTID**	**SJID**
Fashion design and clothing /garment making technology	33 years	Over 20 years	Over 20 years
Tannery and leather work technology	Not offered	3 years	Not offered
Levels of courses Fashion design and clothing/garment making technology:			
Artisan	√	√	√
Certificate	√	√	√
Diploma	√	√	√
Tannery and leather work technology:			
Artisan			
Certificate		√	
Diploma		√	
		√	

Number of students			
Fashion design and clothing /garment making technology	120	83	50
Tannery and leather work technology	Not offered	60	Not offered
Objectives of the courses	Impart knowledge, skills and attitude in fashion design Impart knowledge, skills and attitude necessary for self-reliance Prepare trainees to confidently enter the world of work Empower trainees with sustainable skills	Impart employability skills to learners Produce skilled learners for self-dependency Develop competence skills in the field of fashion design to be creative and innovative	Impart technical skills to trainees Make trainees self-reliant Enable trainees to apply design techniques in various areas Practice fashion production with environmental consideration
Trainers'/tutors' qualifications in special TVET			
Diploma	4	3	4
Higher diploma	3	0	0
Undergraduate degree	3	4	2
Masters degree	2	0	0
Total	12	7	6
Prevalent disabilities among trainees *(multiple responses allowed)*			
Low vision		√	√
Physical challenge/handicap	√	√	√
Cognitive/intellectual/mental deficient	√		
Developmental disorders		√	
Hearing impairment	√		√
Multiple disability	√		
Products the trainers teach trainees to design and construct *(multiple responses allowed)*			
Clothing	√	√	√
Intimate apparel	√		√
Handbags	√	√	√
Jewellery	√	√	√
Eyewear			
Shoes	√	√	√
Soft furnishings	√	√	
Beadwork	√		√
Fabric colouration/decoration		√	√

The TVET institutions have been offering training to persons who are abled-differently. KTTID has offered fashion design course for over three decades, while MTTID and SJID for more than two years. Leather technology programme has been on offer for 3 years in MTTID only. The programmes are offered at Artisan, Certificate, and Diploma levels as prescribed by the curriculum in TVET institutions in Kenya approved by the Kenya Institute of Curriculum Development (KICD). The number of trainees currently enrolled in all the three levels of training in Fashion design and clothing/garment making technology at KTTID, MTTID, and SJID is 120, 83, and 50 respectively. The trainees pursuing tannery and leather work technology course total 60 across the programme levels (Table 1). The results concur with ILO (2021) that Kenya experiences massive inequalities in access to TVET, especially in regard to participation of females and PLWDs.

The objectives of the courses as documented in the curricula are to impart the trainees with knowledge, attitude, and sustainable skills that empower them to be self-reliant, employable, creative, innovative, confident, and practice environmentally-conscious production.

Table 1 further shows that, all trainers in the institutions have undergone formal training with KTTID having tutors who have attained diploma (4), higher diploma (3), undergraduate degree (3) and notable Master's degree (2). The trainers in MTTID and SJID are diploma and undergraduate degree holders. The findings contradict KISE (2019) that heads of regular training institutions indicated that the greatest challenge they face in provision of services and training to trainees with disability was lack of trained personnel and lack of adequate resources and unfriendly infrastructure at 30% and 29% respectively. The former is an indicator of low uptake of training opportunities by staff in these institutions which raises the question of lack of reasonable accommodations/inclusion.

The results show that the most prevalent disabilities among trainees of the two courses was physical challenge/handicap reported across all the institutions. Low vision was reported in MTTID and SJID. Cognitive/intellectual/mental deficient was reported in KTTID and MTTID and hearing impairment in KTTID and SJID. Other disabilities of low prevalence include developmental disorders, and multiple disabilities. The finding resonates with Sichari (2016) that prevalent disabilities among Kenyans include mostly visual, hearing, physical, and mental impairment. Although, the TVET institutions bear the name Deaf, they enrol trainees with other disabilities. The diversity in disabilities may have implications on the pedagogy for the trainer in the delivery of curriculum for DfS adoption.

How Curricular Incorporate DfS

Certificate in fashion design and garment making technology

A total of eight units incorporate DfS namely:

1. Entrepreneurship: enterprise social responsibilities to include meaning and importance, and social concerns of the enterprise.
2. Fabric colouration (tie-and-dye and batik), fabric printing: types of dyes include natural ones obtained from wild plants, cultivated flowers, and foods (onions, purple cabbage).
3. Garment cutting: lay planning (determination of fabric requirements) comprises calculation of material sizes with improved layout; save on material; cut trimming correctly using a pattern.

4. Garment making practical (separately women and men): procedure of assembling a given garment; and quality control.
5. Workshop organization and management: ways of improving inefficient method of working; effects of lighting and ventilation in a workshop; safety precautions such as wearing protective clothing, operating manuals for machines, and safety posters; workshop waste disposal includes recycling and availing bins.

Artisan course in garment making

The content of four units relate to sustainability, particularly:
1. Safety and hygiene: specific workshop rules, fire safety, first aid, and hygiene.
2. Material knowledge: the care of fabrics made from natural and man-made fibres (cleaning agents, stain removal, laundering, dry-cleaning, and storage).
3. Garment cutting: relates to laying out which focuses on economy of materials.
4. Garment making: joining/assembling garment parts and fitting.

The fashion design and garment making technology curriculum addresses DfS, in such courses as entrepreneurship, particularly social responsibilities which is a concept in social sustainability. In fabric colouration, the use of natural dyes is an eco-friendly process. Garment cutting ensures only enough fabric is bought, and efficient layout reduces fabric wastage leading to economic and environmental sustainability respectively. Garment making course supports correct garment assembly thus reduce ripping, in addition to quality control: relates to economic sustainability.

The fashion design and garment making technology certificate artisan curriculum also fosters environmental sustainability in the course titled care of fabric made from natural and man-made fibres which enhances longevity. In addition, garment cutting points to economy of materials hence waste prevention. The garment making unit incorporates fitting which fosters a near-perfect fit thus the garment is worn for a longer period: environmental sustainability. The unit on safety and hygiene imparts trainees with knowledge on how to create a safe working environment: economic sustainability. The curricula thus incorporate social, economic, and environmental sustainability. The findings concur with the respondents' assertions about the units that incorporate sustainability namely garment cutting and making, fabric colouration, and entrepreneurship.

Level 4 Leather worker I course

The following courses factor DfS,
1. Occupational Health and Safety: types and caused of accidents in a workshop, contents and uses of a first aid kit, appropriate PPEs in the work place, use of fire extinguishers and emergency buttons and exits, and Workman's Compensation Act and the Occupational Health and Safety Act.
2. Leather technology subjects include,
3. Pattern Making and Cutting: quality control in pattern cutting procedures, and safety and health practices.
4. Material cutting: Economical layout of material, quality control, accuracy, and safety and health practices.

5. Component Preparation: dyes and stains, safety and health practices.
6. Assembling: Quality control, safety and health practices.
7. Finishing- Materials include dyes, stains, and colours, quality control, and safety and health practices.

Business Studies

Introduction to business studies: corporate social responsibility, classification of business resources includes economic (natural and man-made/capital resources), renewable and non-renewable resources. Workshop organization and management instils the creation of an efficient method of working and a conducive working environment: economic sustainability, and stresses on recycling: one of the 3Rs of environmental sustainability.

All the subjects tackle safety and health practices, and quality control: sustainability concepts. The former promotes a conducive working environment, while the latter fosters good quality products thereby longevity. Economical pattern layout and accuracy prevents waste generation. However, the curriculum does not specify which kind of dyes to use (natural or chemical of which the former is sustainable). The trainers may use their DfS knowingness, skills, and attitude to opt for utilizing natural dyes. In business studies a discussion on Corporate Social Responsibility (CSR) aligns with DfS. Further, considering that leather and fashion production are energy-intensive, knowledge on renewable business resources such as energy would propel the graduates to utilize it in their businesses.

Trainers' Knowingness, Attitude, and Practice of DfS

Trainers' knowingness of DfS

The trainers were probed on the sources from which they obtained information about DfS.

Table 2: Respondents by knowingness of DfS

Awareness of DfS (multiple responses allowed)	n	%
Media especially social media	7	35.0
Research on fibres and fabrics	6	30.0
Workshops	5	25.0
TVET fair/exhibition	4	20.0
Market trend observation	3	15.0
Internet	2	10.0
Fashion shows	2	10.0
Embrace current trends	1	5.0
Learning about design	1	5.0
Reading journals	1	5.0
Community outreach projects	1	5.0
Client's feedback	1	5.0
Innovation	1	5.0
Campaigns about green economies	1	5.0
Trends in modern entertainment scenes	1	5.0

Trainers' understanding of DfS

- Clothing that is mindful of people in the production line or value chain, such as worker rights and social welfare.
- Clothing that is mindful of the environment by using recycled materials/items, waste fabrics, and organic cotton.
- Maintaining a process over a period of time by utilizing available resources.
- Clothing that is socially-acceptable.
- Affordable fashion.
- Classic fashion.
- Ethically-made fashion.
- Clothing that promotes economic empowerment of trainees, such as school uniforms.
- Clothing that fosters green and blue economy.
- Cost-effective clothing.

Results reveal respondents' understanding of sustainability concepts: environmental, social, and economic.

Benefits of DfS

Table 3: Respondents by benefits of DfS

Benefits of DfS *(multiple responses allowed)* **Economic benefits**	**n**	**%**
Availability of cheap materials.	4	20.0
Affordable fashion thus consumers save money.	2	10.0
Creates employment	2	10.0
Technological benefits		
Improves trainees' creativity through re-use, recycling.	3	15.0
Innovation and creativity.	1	5.0
Standardized materials thus increase lifespan.	1	5.0
Unique and good quality designs. **Environmental benefits**	1	5.0
Clean and safe environment by recycle, reuse, repack waste, and reduction of harmful emissions.	11	55.0
Reduction of waste generation, for instance modern ways of assembly.	6	30.0
Healthy/safe work environment. **Social benefits**	3	15.0
Consumer education on habits of sustainable fashion.	1	5.0
Upholds minimalism lifestyles.	1	5.0
Fights for human rights such as workers.	1	5.0
Foster social harmony.	1	5.0
Customer satisfaction.	1	5.0
Saves animal lives.	1	5.0

Table 3 shows that the majority of respondents relate DfS to environmental benefits while the social benefit is the least appreciated. There is a needs/gap in the integration of sustainability practices for the trainers in the TVET institutions. The trainers and trainees belong to diverse reference groups such as social groups and communities. Therefore, cultivating the importance of all sustainability gains would further magnify the network of the benefits of DfS, because fashion and leather production and consumption are the leading global pollutants.

Trainers' Attitude toward DfS

Respondents were overwhelmingly positive about DfS for the following reasons:

Table 4: Respondents by attitude toward DfS

Attitude toward DfS *(multiple responses allowed)*	**n**	**%**
Improve/boost sustainable practice for the next generation.	3	15.0
Create environmentally/eco-friendly products.	3	15.0
It is achievable.	3	15.0
Reduce chemical emissions.	2	10.0
Minimal fabric wastage.	2	10.0
Great potential in the programme if well implemented.	1	5.0
Positive to produce creative learners.	1	5.0
Makes the designer a problem solver.	1	5.0
Ready to embrace it.	1	5.0
Buy locally-made products.	1	5.0
Important to the fashion world.	1	5.0
Creates employment (employed or self-employed) for trainees.	1	5.0
Love creativity from waste.	1	5.0
Support it by incorporating in trainees' projects.	1	5.0
Appreciate its positive effect in the environment.	1	5.0

The majority (80%) of respondents reported that DfS is incorporated in the courses. On the other hand, 20% vocalized the negative. The reasons for the former include,

- Supports fairer and safer working conditions.
- Through the CBET curriculum.
- The skills attained enable learners and trainers to focus on detail, creativity, and environmentallyfriendly aspects.
- The KNEC curriculum incorporates research and exhibition.
- It is an aspect of emerging issues in the fashion world to innovate eco-friendly products.
- Trainees can select and focus on what they can do best.
- Makes trainees creative and innovative.
- Most TVETs are conducting this training.
- Trainees use waste to make soft furnishings.

DfS is not incorporated in the courses because the design world in the classroom is knowledgebased not practical.

Trainers' Practice of DfS

Table 5: Respondents by knowingness, attitude, and skill sets required for successful DfS practice

Knowingness, attitude, and skill sets crucial for successful DfS practice *(multiple responses allowed)*	**n**	**%**
Knowingness		
Fashion design knowledge, for instance trends, design thinking.	11	55.0
Creativity.	8	40.0
Innovativeness.	8	40.0
Environmental literacy.	3	15.0
Material/textile science knowledge, for example durability, challenges of using certain fabrics, sourcing.	2	10.0
Attitude		
Attention to details.	2	10.0
Waste sensitive.	1	5.0
Collaboration.	1	5.0
Problem solving.	1	5.0
Skill sets		
Sewing techniques.	4	20.0
Garment cutting.	2	10.0
Good communication.	2	10.0
Research.	2	10.0
Recycling.	1	5.0
Rebranding.	1	5.0
Entrepreneurial/marketing.	1	5.0
Artistic skills.	1	5.0
Pattern development.	1	5.0
Information communication technology (ICT).	1	5.0

Results in Table 5 show that respondents' knowingness prevails over attitude and skill sets. Notably, the latter two may hinder their ability to successfully transfer important DfS practices to their trainees. Consequently, this may act as an impediment to the trainees to practice DfS.

How the departments have benefited from adopting DfS in trainees' projects

- Support local communities.
- Encourages mindful consumption of fashion products.
- The majority of the trainees have become innovators, self-reliant, and job creators.
- Enhanced trainees' boldness, assertiveness, and creativity to design and produce biodegradable and transformable fashion products.
- Makes trainees appreciate and embrace their cultural heritage.
- Produce fashion products by reusing, upcycling, and recycling clothing items and materials thus savings are made. The articles are exhibited and sold in TVET fairs.
- Promotes safer working environment for trainers and trainees.
- Makes the course relevant to the current global environmental issues.
- Trainees do economical pattern layout hence reduce wastage.
- Trainees adhere to environmentally-friendly waste disposal.

Challenges departments encounter in adopting DfS

Adopting DfS creates its fair share of challenges to the department related to institutional, consumer, and financial issues:

Institutional concerns

- Limited time because creativity is time-consuming yet the courses have a tight schedule with limited practice time. The trainees write examinations every year.
- Shortage of equipment, particularly modern ones.
- Lack of clear academic grading.
- Limited resources for research and implementation.
- Lack of materials.
- Lack of finance to run the programme.
- Lack of proper guidance and policy.
- Challenge of sourcing eco-friendly materials.
- Trainees undecided because the programme is broad, thus selecting one item may not be beneficial to some trainees.

Consumer concerns

- Acceptability by consumers.
- Slow adoption.
- Limited accessibility for consumers.

Financial issues

- Pricing of the products.
- High cost.

The results clearly point to institutional challenges as the major deterrent to the success of DfS practices despite consumer concerns such as product acceptability, slow adoption, and limited accessibility. The findings resonate with Chipambwa (2024) that upcycling faces myriad challenges. The process is time-consuming due to the uniqueness of the products. Pricing the products is difficult as customers considered them as having inferior quality. Further, customers may have a negative attitude toward the products as they prefer those made from new fabric.

Units that incorporate DfS

The respondents outlined seven units each in fashion design and clothing/garment making technology and tannery and leather work technology in which DfS is incorporated namely,

Table 6: Fashion design units that incorporate DfS

Unit Name	Unit Description
Garment construction practical	Garment assembly from designing, cutting to making/joining.
Accessory making	Use locally-available materials.
Fabric colouration (batik, tie-and-dye)	Use the techniques to renew old garments.
Fashion design, clothing construction	Sketch designs that have classic styles.
	Construct garments using the most economical technique.
Cutting technology	Lay patterns in the most economical way.
Environmental literacy	Competencies required to control environmental pollution.
	Comply with workplace sustainable resource use.
	Identify environmental legislation.
	Implement and monitor activities on environmental protection.
Entrepreneurial skills	Developing business innovation strategies.

New markets.

Motivating workers.

Despite experiencing numerous institutional challenges as stated, the trainers have successfully implemented DfS practices in some of the courses in the curriculum that they teach (Table 6). The practice shows a willingness by the trainers to enhance sustainable practices in fashion and clothing design and tannery and leather work technology.

Strategies the departments employ to incorporate DfS

Table 7: Respondents by strategies adopted to incorporate Df

Strategies adopted in incorporation of DfS *(multiple responses allowed)*	**n**	**%**
Students are encouraged to do economical pattern layout.	15	75.0
Trainers encourage students to use new scrap fabric for projects.	13	65.0
Procure and use natural dyes in fabric colouration.	12	60.0
Students are taught how to mend fashion products.	11	55.0
Developed new courses that integrated sustainability.	10	50.0
Re-orient existing courses to incorporate sustainability.	10	50.0
Adhere to environmentally-friendly disposal of effluent from fabric colouration.	10	50.0
Trainees are assisted to design and construct multi-functional fashion products.	10	50.0
Trainees are guided to design and construct apparel for persons with special needs eg. Elderly, PLWDs.	10	50.0
Trainees are guided to design and construct classic fashion products.	9	45.0
Trainers encourage students to restyle products into apparel.	9	45.0
Trainers stress on trainees to design and construct reversible apparel.	8	40.0
Entrepreneurship units emphasize on workers being valued.	8	40.0
Trainers stress on trainees to design and construct reversible fashion accessories.	7	35.0
Students are facilitated to design and construct transformable fashion products.	6	30.0
Trainers encourage students to design and construct reversible soft furnishings.	5	25.0
Trainers emphasize to trainees to construct long lasting fashion products.	5	25.0
Trainees are required to design together with real clients/end-users.	5	25.0
Trainees are encouraged to adopt ethnic dress styles of diverse African communities in their projects.	5	25.0
Students are encouraged to use bio-degradable fabrics.	5	25.0
Trainers stress on the trainees to use Kenyan made fabrics and materials.	4	20.0
Students are encouraged to empower the community culturally and economically	4	20.0
Seek fabric donations from textile manufacturing firms.	3	15.0
Sought for leather scraps from leather tanneries and designers.	3	15.0
Invite resource persons to speak to trainees and staff on sustainable fashion.	2	10.0
Seek fabric donations from fashion houses.	2	10.0
Seek fabric donations from apparel manufacturing firms.	1	5.0

Table 7 reveals that the focus is on trainees being instilled the DfS practice in their projects that incorporate such concepts as upcycle, mend, restyle, transformable, reversible, use end-of-life fabrics, buy local, and community engagement. Evidently, the respondents are acting as change agents or champions.

Trainees and DfS

Sustainable products created by trainees

The results reveal trainees create soft furnishings, apparel, fashion accessories, and engage in halfscale garment making. Fashion accessories include earrings, necklaces, sandals, beadwork baskets, bags, hats,

scarves, and ties. The soft furnishings comprise duvéts, curtains, backrests, wall hangings, floor and baby play mats, lampshades, pillowcases, nettings, centre pieces, throw cushion covers, bedcovers, loose covers, carpets, and rugs. Sustainable principles are employed in fabric colouration and in practical/studio projects by constructing a half-scale garment. The finding echoes Simmons (2017) that with appropriate support adolescents and youth living with disabilities can develop into adults who lead contributing and satisfying lives in the community. The special TVET graduates, despite their disabilities but equipped with relevant knowingness, and skill-sets, as well as a positive attitude of and toward DfS shall practice it in the industry, thereby foster sustainable production and consumption.

Trainees' Reaction to DfS

The trainees are predominantly positive about adopting DfS, which is expressed by such sentiments as 'excited', 'impressed', 'happy', and 'like it'. The trainees embrace DfS, understand the need for sustainable production and consumption, keep wastage to minimal due to change of attitude towards use of fabric, and put much effort to create more sustainable fashion products. Nonetheless, some trainees do not seem to understand the concept. Such trainees prefer easy and fast work, and lack capital to purchase sewing machines and materials. Consequently, upon graduation, only a quarter of the graduates venture into fashion design, while the rest abandon the discipline. The respondents added that the study topic is relevant and well-captured in the new CBET programme.

Conclusion

With proper training and DfS-oriented curriculum, trainees living with disabilities enrolled in special TVET institutions are empowered to engage in DfS. The course objectives are DfS-oriented to some extent. Therefore, it is increasingly important for design educators in special TVET and other higher education institutions (HEIs) to be well-versed with DfS to facilitate the objectives' attainment. DfS is incorporated in both studio-based and theory units. The former include pattern making, material colouration, and garment cutting and making. The theory units comprise business studies and occupational health and safety. The trainers' employ their knowingness, attitude, and skill-set/practice of DfS in developing and delivering curricula, which has benefited the departments, particularly by the students adopting DfS in their course projects by designing and producing sustainable soft furnishings, and fashion and leather products. Nonetheless, DfS adoption experiences numerous institutional challenges, as well as consumer, and financial obstacles. ESD is the key to achieving other SDGs such as sustainable fashion and leather production and consumption. Trainers play a crucial role in the innovative learning process. Due to trainees' positive attitude toward DfS, they shall either continually improve existing products/solutions/outcomes or create radically new ones that are distinctively sustainable. Both the trainers and trainees contribute to Kenya's fashion and leather industry's substantive engagement with DfS, 'greening', and competitiveness. Further, they are game changers fostering DfS.

The authors recommend capacity building: conduct workshops and develop a DfS module/toolkit for the special TVET trainers to enhance their knowingness, attitude, practice, skill-sets, and value concerning DfS. A tracer study to be conducted on special TVET trainees' knowingness, attitude, value, and practice of DfS: fashion design and leather technology. The trainees are future design practitioners and potential change agents.

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Improving Rural Primary School Education with Classroom Design: A Sustainable Method

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Abstract

The aim of the study is to investigate awareness and understanding of sustainability education in rural primary schools of Jabalpur, central India. A total of 72 participants (school children) were selected, out of which 29 were males and 43 were females. Through the interviews, and observational studies the findings of this research study showed no knowledge of sustainability. From interviews, teachers reveal that they face challenges in teaching sustainability topics and strategies used to engage children. Children responses showed no knowledge of sustainability. From observational studies, we could conclude there is no classroom activity related to sustainability education, no environmental topics, no integration of sustainable practices into daily routines. Also, there are no eco-friendly facilities and no outdoor learning spaces. Thus, there is a great need for sustainability education in rural primary schools. Thus, sustainability education in everyday learning should incorporated through physically sustainable classroom design by using corrugated sheets to create interactive furniture and learning aids for teaching and learning. Thus, children can be inspired to become environmentally conscious citizens and practices more sustainable future.

Introduction

Particularly in rural areas, the significance of sustainability education has gained recognition in recent years as an essential part of elementary education. Roughly 90% of Indians live in rural areas, according to the National Sample Survey Office (Thomas and Jayesh, 2016). These areas frequently deal with a wide range of difficulties, such as little resources, poor education, and little exposure to environmental problems. Because rural areas are essential to the country's overall sustainability efforts, these characteristics make the distribution of sustainability knowledge both a difficulty and a requirement.

A generation that is environmentally conscious and able to make sustainable decisions needs to be raised through sustainability education, which includes teaching about the environment, sustainable development, and the interconnectedness of ecosystems. None the less, a major obstacle is the dearth of widely accepted sustainability education initiatives in rural India, especially in elementary schools. According to Chhokar *et al.* (2007), there is a significant void in the country's attempts to encourage environmentally responsible behavior and sustainable practices when these programs are absent. Given that rural communities are frequently more closely linked to natural resources and ecosystems; it is troubling that there is a lack of implementation of sustainability education in these places. This is because local knowledge and involvement in sustainability matters more in these locations.

Prior research has brought attention to the difficulties and possibilities involved in incorporating sustainability education within the academic program. According to Tilbury (2011) and Sterling (2001), for example, good sustainability education should encourage critical thinking, problem-solving abilities, and a feeling of environmental responsibility in addition to imparting knowledge. However, due to a shortage

of qualified teachers, subpar instructional resources, and poor infrastructure, these components are absent from many rural schools (Gough & Sharpley, 2005). This calls for creative ways to make sustainability accessible and interesting for kids in the classroom on a daily basis.

The purpose of the study is to assess primary school students in rural Jabalpur, central India, regarding their present knowledge and comprehension of sustainability principles. It aims to identify the obstacles that educators have when delivering sustainability education, including scarce resources, inadequate training for teachers, and trouble keeping students' attention. The study will also evaluate the degree to which lessons on sustainability and the promotion of sustainable behaviors are incorporated into the curriculum. The study also looks at creative solutions, such as making engaging, environmentally friendly classroom furniture and learning tools out of corrugated sheets. We will track how these environmentally friendly classroom designs affect student participation, academic performance, and environmental consciousness.

Literature Review

Sustainability education has gained global importance as societies recognize the need for environmental stewardship and sustainable development. It aims to equip individuals with the knowledge, skills, and values necessary to make informed decisions that contribute to environmental, economic, and social sustainability. The United Nations Educational, Scientific and Cultural Organization (UNESCO) emphasizes the role of education in fostering sustainable development, advocating for its integration across all levels of education (UNESCO, 2014).

Since early exposure can influence attitudes and actions that last a lifetime, primary education is essential for imparting sustainability concepts (Tilbury, 2011). Studies indicate that introducing young children to sustainability education helps promote environmental consciousness and conscientious citizenship (Davis, 2010). Yet, the success of these educational programs frequently hinges on the accessibility of materials, the level of teacher preparation, and the incorporation of sustainability into the curriculum.

There are significant difficulties in implementing sustainability education in rural areas, especially in developing nations like India. Many rural schools lack basic infrastructure, l*et al.*one resources for specialized educational programs, according to the National Council of Educational Research and Training (NCERT) (NCERT, 2012). According to Chhokar *et al.* (2007), access to qualified teachers and environmental education resources is frequently a problem for rural schools. Studies of rural Indian schools have shown that a greater lack of knowledge and comprehension of sustainability among students and teachers exacerbates these difficulties (Bordoloi & Bordoloi, 2016).

The study found notable deficiencies in the teaching of sustainability in rural Jabalpur, central India, primary schools. Teachers were found to be ill-prepared and ignorant when it came to teaching sustainability-related subjects. The two main challenges mentioned by teachers were a lack of compelling teaching tactics and inadequate training. Studies based on observation verified that there were no environmental themes covered in the classroom, no sustainability-related activities, and no sustainable practices incorporated into everyday life. This is consistent with research by Sterling (2001), who found that environmental education is frequently neglected in traditional educational systems, particularly in environments with little resources.

Considering the shortcomings found, creative methods for incorporating sustainability education into the curriculum are obviously needed. The study suggests making interactive furniture and educational materials out of physically sustainable classroom designs, including corrugated sheets. These designs serve as real-world examples of sustainability concepts in addition to making learning more interesting (Gough & Sharpley, 2005). These tools' actual use can assist close the knowledge gap between theory and practice, giving students a greater grasp of sustainability.

It has been demonstrated that incorporating sustainable classroom designs improves student learning by bringing abstract ideas to life (Wals & Kieft, 2010). Children were seen to interact with the learning materials more actively in the study's context, developing a more tangible grasp of sustainability. In addition to teaching children about eco-friendly activities and the utilization of recycled materials, this technique also introduces them to the idea of resourcefulness. Schools can encourage students to embrace sustainable practices in their daily lives and ultimately contribute to the development of environmentally conscious citizens by implementing these components into the classroom (UNESCO, 2014).

Methodology

Questionnaire Focusing on Knowledge of Sustainability

The questionnaire followed by Mahat *et al.* (2019) has been modified according to the context of rural primary schools, Jabalpur, Madhya Pradesh. The questionnaire involves three variables focusing on knowledge of sustainability. The first variable focused on knowledge of recyclable and non-recyclable materials. There are ten items in the form of coloured picture, children were asked to see picture and give answer ‘yes’ or ‘no’ based on materials which are recyclable and non-recyclable. The other variable focused on evaluating knowledge of sustainability, there are three components of sustainable development – social, economic, and environmental. Children were asked to answer these pictures by Yes = 2, No = 1, Not sure = 0. Another variable is the behaviour of sustainability which is again divided into three parts. First part namely six items of reducing practice, six items of reusing practice and six items of recycling practice. These variables are evaluated on scale of 2 = Always, 1= Sometimes, and 0 = Never modified by Leeming *et al.* (1995) for the children’s environment attitude and knowledge scale (CHEAKS) Ozturk, D. (2010). These three variables are modified according to the surroundings in rural Jabalpur, central India.

Interviews

Due to the time constraint imposed by the school principal for conducting interviews with teachers, and with the goal of causing the least impact possible during the course of courses, group interview or focus group interview, suggested by Merton *et al.* (1956) was adopted in our study. According to Patton (2002) and Flick (2009), a group interview or focus group interview is one in which individuals to be questioned are met in small groups due to time limitations and a lack of resources. The goal here is still to collect the perspectives of each interviewee, rather than data derived from hypothetical debates on the topic; that is, even while it is developed in a group, a group interview is still an interview, according to Patton (2002).

Direct Observations

Direct observation as a participating viewer was the observation technique used and it followed typologies by Gold (1958) and Merriam (2009). All children of class V were investigated during school hours. During the process, teachers let go of several teaching resources such as songs, plays and games with the objective to reach the goals suggested. The observation of interaction between children and teachers and environment during the activities could help in the process of analysis of how school has developed practices related to sustainability.

Results and Discussion

Student Demographics

The study was conducted in Jabalpur district of Madhya Pradesh, India. Before the study began, Ethical permission was obtained. The study only looked at four rural primary schools, from each school 20 children participated. Only 12 children participated from one of those schools. [Table 1]

Table 1. Demographic Data

Class V children	**Male n = 29**		**Female n = 43**	
	Mean ± SD	**Range**	**Mean ± SD**	**Range**
Weight (kg)	22.76 ± 1.57	25 - 20	23.18 ± 1.91	26.5 – 20
Height (m)	1.02 ± 0.02	1.04 -1	1.04 ± 0.03	1.09 – 0.99
BMI	21.76 ±1.52	24.7-19.38	21.29 ± 2.20	26.37 – 18.09

Questionnaire Focusing on Knowledge of Sustainability

Figure 1 shows the responses to knowledge of recyclable and non-recyclable materials. The items that show the highest incorrect percentage is plastic at 40.32 percent, glass bottle at 48.96 percent, aluminium cans 40.32 percent, newspaper 37.44 percent, stone at 42.48 percent. The highest correct percentage is raw food at 48.24 percent, food polystyrene at 36 percent, cartoon box at 30.24 percent. This demonstrates clearly that major respondents lacked the necessary knowledge to differentiate between recyclable and non- recyclable items. [Figure 1]

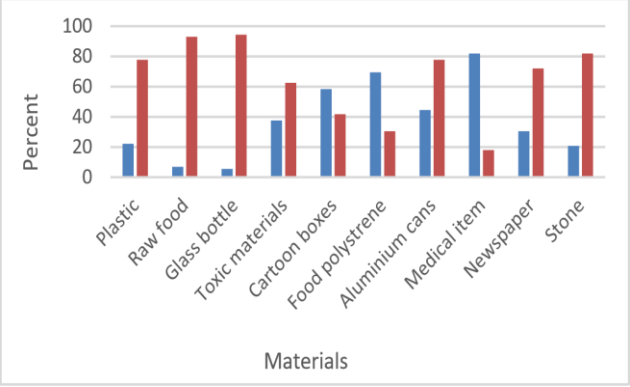

Figure 1. Knowledge of recyclable and non-recyclable materials

Analysing sustainability knowledge for 18 items (Figure 2) children were asked questions with showing pictures about having awareness or knowledge regarding socio, economic, environment. Most of the children answered 'no' for not having knowledge regarding any of these factors. Clearly shows overall respondents' knowledge of sustainability is lacking. However, there are items with a low percentage of 'yes' responses. [Figure 2]

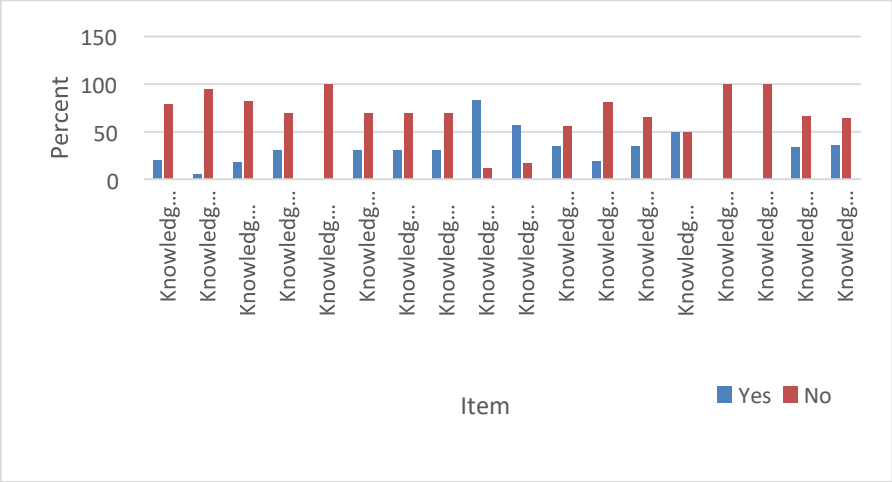

Figure 2. Frequency of sustainability knowledge

The frequency variable is analysed next, to determine the sustainability practice of reducing. The Study findings (Figure 3) show that reduce item 1 "electricity conservation practice by switching off the lights when not in a room" shows a high percentage of agreeing with 72.22 percent stating that they do practice that. Reduce item 2 "wasting of electricity by not switching off lights" shows agreement with 66.66 percent stating that they do practice. Reduce item 3 "Not wasting of water" shows a high agreement with 45.83 percent stating that they do practice of not wasting the water. Reduce item 4 "wasting of water" shows high agreement with 38.88 percent stating that few practices of not wasting water and few disagree. Reduce item 5 "usage of tissue instead of handkerchief shows an agreement with 39 percent of not using. Reduce item 6 "minimizing usage of plastic bag" shows disagreement with 45.83 percent stating that they use it and few with 22.22 percent respondents agree not to use plastic bags. [Figure 3]

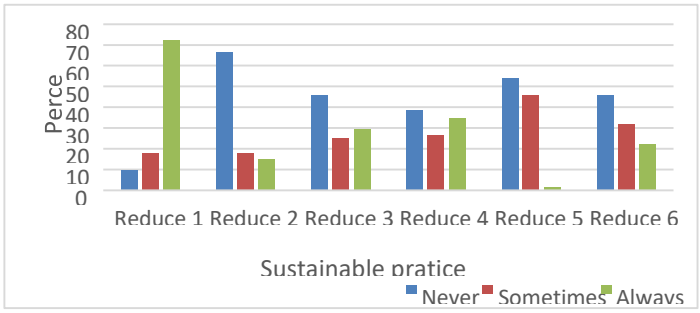

Figure 3. Frequency of reduce practice among school children

Referring to Figure 4, the item showing the highest percentage of recycling practice is recycling item 3 – "selling old newspaper to be recycled" with 58.33 percent of respondents said they always practiced this, while 41.66 percent of respondents said they practice sometimes. The rest of all recycled items did not show positive responses towards frequency of practicing recycling items. [Figure 4]

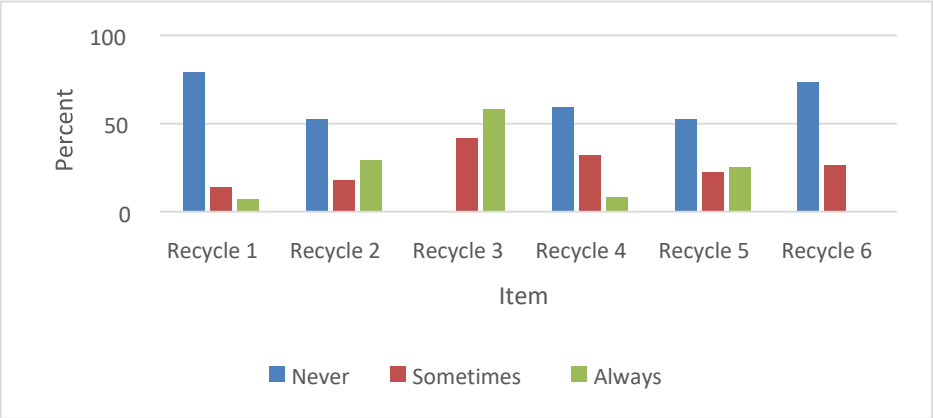

Figure 4. Frequency of recycle practice among school children

The frequency distribution of respondents' answers towards reuse practice shown in Figure 5. The highest percentage of positive response was for reusing item 1, 3, 4 and 6 (usage of plate, usage of lunch box, usage of used paper, usage of paper both the sides) were 100 percent, 41.66 percent, and 58.33 percent. For other reuse items 2 and 5 (use of polystyrene and bringing bag to market) respondents choose "sometimes" with 81.94 percent and 47.22 percent. Basically, the study findings imply that the efforts towards application of sustainability must be follow Agut *et al.* (2014) who agree that children as members of a community need to be equipped with knowledge, and education towards sustainability development needs to be implemented. Also, Siraj-Blatchford (2009) further agrees that early childhood education plays an important role in achieving sustainable development and this educative role is best played by teachers. Ayeni & Adelabu (2012) emphasize that such education should be ongoing until they reach adulthood so that they really understand and are aware of the importance of preserving the environment. [Figure 5]

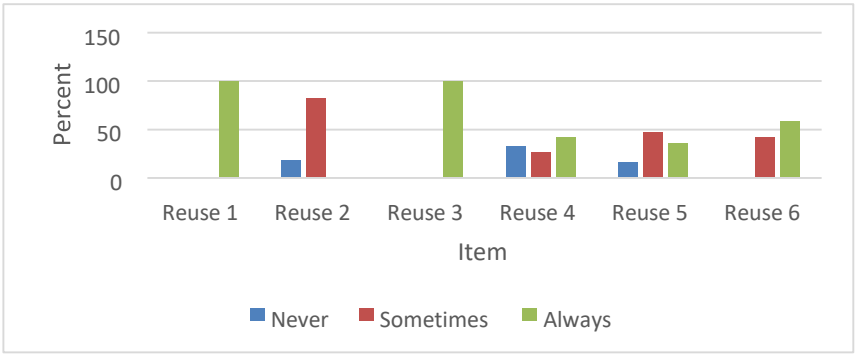

Figure 5. Frequency of reuse practice among school children

Interviews

The group interviews began with the researcher introducing herself. Then she described how the interview would be conducted and began it. A total of 5 teachers from the same school participated in the interview. The interviews followed a semi-structured script, derived from Farias (2016), who conducted a study with comparable objectives on a higher education level. The interview focused on sustainability in general and specifically to sustainability in the school or educational context. Only two teachers are aware of the sustainability development. None of the teachers was able to give a theoretical definition of sustainability. Our findings are like Teo *et al.* (2014). The second part of the interview was to get insights of teaching practices of sustainable knowledge. Only one teacher (out of 5 teachers) explained their teaching practices which were earlier performed in classes, teacher connected with environmental especially natural resources and renewable energies by covering three dimensions of sustainability. Also, teachers discussed integrating environmental education into school curriculum was not favoured because environmental education in various subjects is not given that much importance.

Similarly, Kimaryo (2011) reported that teachers' teaching practices in integrating environmental education varied from one subject to another. Also suggested that environmental education with integrating ideas of sustainability should be included in the curriculum as an independent subject or as specific topics.

Direct Observations

From observational studies, we could conclude there is no classroom activity related to sustainability education, no environmental exploration was used, no teaching aid/tools used for teaching practices. Also, there are no eco-friendly facilities and no outdoor learning spaces. Furthermore, the importanc of introducing outdoor learning needs to be taken into consideration by all (designers, public & private institutions as well as residents). It has been proven through research Marcus *et al.*, (1998); Cosco *et al.*, (1999); Marcus *et al.*, (1999); Olds and Anita (2001); Fjostoft, (2004) that bringing outdoor environment into the teaching practice for sustainability knowledge. No schools have adopted green building standards, no regular workshops and resources for sustainability education, lack of standardized curriculum for sustainability and no classrooms are interactive. Our findings are like the study of Ayeni and Adelabu (2011) who reported that quality assurance practice towards sustainability is at the average level in secondary schools. Durosaro (1998) reported that if the educational curriculum is well operated while the school facilities are lacking and badly managed, the result of the teaching/learning activities will be negative. This implied that there is a positive relationship between a good school environment and effective teaching and learning activities. [Figure 6]

Figure 6. Classroom Infrastructre

Conclusion

The study emphasizes how important it is to incorporate sustainability teaching into rural primary schools, especially in areas like central India's Jabalpur, where there is frequently a lack of resources and facilities for education. Since 90% of the country's population lives in rural areas, ignoring these areas in sustainability education programs can impede the achievement of national environmental objectives. Teaching sustainability to kids at an early age is crucial to raising a generation of environmentally conscious adults who can work toward a sustainable future**.** The study investigated creative ways to integrate sustainability education into regular learning in order to address these issues. Students may now interact with sustainability concepts in a concrete sense thanks to the introduction of physically sustainable classroom designs, such as the creation of interactive furniture and learning aids out of corrugated sheets. Children were able to engage with educational materials manufactured from recycled materials through this hands-on approach, which improved their knowledge of the environment. Children using these environmentally friendly teaching resources were seen to have a very favorable effect. In addition to becoming more involved in the educational process, children also acquired useful knowledge about sustainability. Recycled materials were used to make classroom furniture, which was a useful illustration of environmental preservation and inventiveness. Young learners found that this practical learning method worked well for making abstract notions of sustainability more relevant and concrete.

Acknowledgement

We like to thank children and teachers who took part in this study from the rural elementary schools in Jabalpur, central India.

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Track 3 Biodiversity and Ecosystem Services

3a. Life on Land

Abstracts

Submission ID: 21

Coexistence amidst Modernisation: More-than-Human design for Sustainable Futures

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Abstract

Across the ages, humans and animals have contended for natural resources, sharing the role of Earth's stewards, equitably. This initial equilibrium facilitated harmonious coexistence, bringing mutual benefits to both entities. Yet, with the progression of modernization and unregulated urban expansion, anthropocentric spaces emerged, disregarding crucial non-human stakeholders' integral to the ecosystem. This transition from a once harmonious and balanced ecosystem to a human-centric, greed-infested one has created a vicious circle, deemed wicked problems (Irwin, 2018). Earlier design principles, despite numerous efforts, prove inadequate as they neglected the intricate interdependencies between human and non-human stakeholders. This research aims to investigate: a. how the potential connection between unregulated human-centric design and global human-animal conflicts can be analysed? b. how can community engagement and co-creation strategies be optimally utilized to incorporate a wide range of stakeholders' participation? c. how effectively does the More-than-Human design framework translate diverse stakeholder values into tangible aspects in the development of educational and sustainable design solutions? This research is inspired by the work of Berilsu Tarcan (2022) and Kande Kazadi (2016). Present research holds significant implications for UN Sustainable Development Goals (SDGs), particularly aligning with the SDG 15, "Life on Land" subset 15.5 "Protect Biodiversity and Natural Habitats." The focus is on preserving biodiversity in and around mountain and hilly regions within this research, where issues like deforestation, excessive land use, and resulting land degradation contribute to the extinction and migration of species, leading to ecosystem collapse. This collapse, in turn, poses a threat to the health and wellbeing of both human and non-human inhabitants in these spaces, emphasizing the interconnectedness of environmental and community well-being. To cater to the aforesaid objectives, Anegundi (heritage village surrounded by hills) and Kodagu (famous hill station), two landscapes in the Deccan Plateau of Southern India, have been chosen as case studies. Their historically harmonious coexistence is now under strain due to conflicts with non-human stakeholders, exacerbated by rapid and unchecked urbanization. This research seeks expert opinions from designers, ecologists, and specialists in pertinent fields along with exploring community participation and various stakeholders' roles through the lens of co-creation. Case study analysis shows that preservation of these ecosystems not only benefits communities and livelihoods by providing food, shelter, health, and occupation but also contributes to the sustainability of these vital aspects of human as well as nonhuman well-being. Further, the research examines the complexities of human-centric development, offering a global blueprint for fostering sustainable and harmonious relationships between humans and non-human stakeholders within a larger regional setting. This research culminates to an interactive educational game to broaden awareness among diverse audiences, emphasizing their pivotal role in sustaining ecosystem functionality. Along with its findings, it holds significance for researchers interested in investigating the interplay between human-centric design and the global issue of human-animal conflict.

Submission ID: 209

Habitat Quality of Farmland for Sarus Crane in the Greater Lumbini Area, Nepal

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Abstract

Urbanization and fragmentation decrease habitat availability and connectivity in the farmland, which tends to shrink the provision of ecosystem functions and taxonomic diversity. To understand the cumulative effects of road network and urban area on the large wading birds in the Greater Lumbini Area, this study assesses the responses of Sarus crane to spatial habitat quality generated by Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) Habitat Quality Module based on land use and land cover including experts' knowledge on habitat suitability, accessibility and threats to the birds. The results indicated that the habitat quality of 358.9 sq. km has changed from 2017 to 2023, of which 72.5 sq. km of the area changed from very high to very low, and 80.5 sq. km changed from very high to low habitat quality. The habitat quality of the southern part is higher than the northern part of the study area. The distribution of Sarus cranes in pre-monsoon, monsoon, and post-monsoon were significant to habitat quality, preferring very high-quality habitats for nesting and foraging. This study is crucial for conserving the quality of farmlands and can contribute to developing conservation policies for the large wading birds in the farmlands of lowland Nepal.

Keywords*: fragmentation; habitat quality; InVEST model; large wading birds; lowland*

Submission ID: 227

Control and Management of Invasive and Alien Plant Species Essential to Achieving Sustainable Development Goals: A Comprehensive Assessment

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Abstract

Invasive and alien plant species (IAPs) present a significant threat to global ecosystems, impacting water quality, agricultural productivity, flooding, and biodiversity. This literature review explores the extensive ecological and socioeconomic consequences of IAPs, with a particular focus on South Africa, where over 10 million hectares are currently affected. The introduction of approximately 9,000 IAPs to the country has led to 198 being classified as invasive, posing serious challenges to local ecosystems. Beyond ecological concerns, the study emphasizes the broader implications for achieving Sustainable Development Goals (SDGs). IAPs can exacerbate food insecurity, diminish water resources, and increase the risk of vector-borne diseases, hindering progress towards SDGs 2 (Zero Hunger), 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), and more. Despite the pervasive impact of IAPs on multiple SDGs, there is a notable gap in the literature assessing the contribution of IAP eradication to sustainable development. The study aims to fill this gap by investigating how IAP control aligns with the SDGs, analyzing successful case studies, examining potential trade-offs, and assessing policy frameworks. Methodologically, the research will utilize existing evidence on the socioeconomic impacts of IAPs, focusing on case studies such as the effects of Eichhornia crassipes in Ethiopia and the spread of Mesquite in South Africa. The evaluation of successful management projects, like the control of *Opuntia monacantha* using biological agents in South Africa, highlights positive impacts on SDGs 2, 3, and 15. Furthermore, the study proposes a mixed-methods approach involving surveys and interviews with experts, policymakers, and local communities to understand their perspectives on the link between IAP management and SDGs. The online surveys will explore the connections between specific SDGs and the impact of IAPs, engaging with various stakeholders to gather comprehensive insights. The anticipated outcomes include a comprehensive assessment of current knowledge on IAP control, identification of effective methods and challenges, and actionable policy recommendations aligned with SDGs. Ultimately, this research aims to provide scientific evidence supporting the development and implementation of effective IAP control programs while raising awareness of the critical need for action in achieving sustainable development objectives.

Submission ID: 228

Balancing the Goals of Sustainable Community Wellbeing and Habitat Restoration in Managed Retreat Proposals: A Perspective from the Indian Sundarbans

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Abstract

Coastal biodiversity is under significant threat from rising sea levels, ocean acidification, and over-exploitation of marine resources. Additionally, the increased pressure from human populations in coastal areas further jeopardizes biodiversity. Managed retreat has been proposed by environmental conservationists as a means of maintaining coastal biodiversity while looking for the wellbeing of populations living in vulnerable areas. Any managed retreat model evaluates the regional multi-hazard setting that would ideally consider regional influences such as the combined effects of cyclones, riverine and oceanic floods, etc. Related simulations of these hazards can help to estimate the nature, extent and patterns of submergence of, for example, delta regions. Managed retreat solutions embrace the spirit of SDG 14, which seeks to conserve water resources in sustainable way.

Several studies have addressed the multifaceted challenges faced by governments and stakeholders at different levels while promoting strategic managed retreat models. Present-day research is seeking to investigate the social, cultural, and economic challenges of implementing managed retreat for achieving climate resilience, biodiversity conservation, sustainable community development, and informed policy advocacy. Against this backdrop and in seeking to assess the present situation of areas under threat, this paper identifies the Sundarbans delta region of India as a case study. In 1989, UNESCO declared this region as the "Sundarbans Biosphere Reserve" because of its unique biodiversity, which is spread across the world's largest mangrove forest. Research suggests this area could stand to lose between 42% to 80% of its pristine area due to the decline of the mangrove forests, rise in sea level and frequent cyclones. The Indian government drew up plans for a Delta Vision: 2050 which seeks not only to conserve the biodiversity through retreat management but also to improve overall wellbeing of affected communities. Nevertheless, experts and various stakeholders have expressed concerns regarding the advocacy of 'phased and systematic outmigration' of local people who have lived in tandem with this deltaic landscape for generations.

The study explores local apprehensions about losing culture, traditions, and livelihoods due to forced migration.In this context, the study seeks a solution that is at the intersection of design for locals and for the environment, and is one that can ensure that affected communities do not succumb to changes to their original habitat and loss of their cultural heritage and livelihood. It advocates for co-designed solutions—developed through collective, lived experiences—that support both environmental goals and community needs. Solutions embracing indigenous traditions and culture not only act as catalysts to build a sense of belonging within the community but also help sustainable livelihoods thrive in the face of uncertainty. They also ensure justice and equity among and for displaced communities and help toward the development of new policies for the preservation of indigenous heritage. The study hope such an innovative alternative prototype can serve as a guide in making policy directions while even considering strategic retreat with the goal of long-term and holistic sustainable development.

Submission ID: 309

Interaction Networks between Fig-Fig Wasp System and Birds: A Case Study on *Ficus Tinctoria* in Xishuangbanna, Southwestern China

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Abstract

The evaluation of spatial utilization patterns at the community level is essential for comprehending the segregation of species across various habitats and the extent of species overlap, which encompasses complementarity and redundancy. The vertical stratification of fig resources within the canopy layers offers additional ecological niches for frugivorous, thereby facilitating species coexistence and augmenting the diversity of frugivorous within forest ecosystems. Nonetheless, a comprehensive investigation into the interplay between frugivorous and figs within the vertical spatial dimensions of *Ficus* at the community level remains a relatively unexplored avenue of research. *Ficus tinctoria* indigenous to the Xishuangbanna region, exhibits a distinct phenological pattern compared to other *Ficus* in its climatic adaptation and timing of fig production, notably yielding a substantial quantity of fig wasps during the winter months. Prior scholarly work has postulated that the *F. tinctoria* has evolved this unique phenological adaptation to optimize the reproductive capabilities of female trees, a strategy that is highly advantageous for seed dispersal. In order to elucidate the interrelationships between *F. tinctoria* and avian species across various forest canopy strata, as well as to identify the factors that influence avian foraging preferences for male and female figs of *F. tinctoria*, the application of network analysis to examine the community-scale interactions between avian species and *F. tinctoria* can delineate the architecture of the frugivory network. Such insights are pivotal for forecasting the dynamics of ecological communities and the functional attributes of the ecosystem. Through our study, we found that *F. tinctoria* provides food resources for 58 bird species during the dry season (November to April), making it an important foundation species. Birds show a preference for consuming female figs of *F. tinctoria* compared to male figs, and they exhibit different spatial ecological niches, complementing each other between the upper and lower canopy networks. The vertical structure of the fruiting network promotes coexistence of frugivores and seed dispersal. When birds feed on female figs, they have a positive impact on the fig-wasp mutualism system. However, when birds consume male figs or fig wasps, it has a negative impact on the fig-wasp mutualism system. The intensity of avian consumption of ripe *Ficus* figs leads to a decrease in 55-89% of seeds and 85-93% of fig wasps. The size, nutritional content, and color of female and male figs can influence bird selection. Female figs of *F. tinctoria* are more attractive to birds, and the phenological period of *F. tinctoria* effectively facilitates seed dispersal through bird feeding. The study suggests that the *F. tinctoria* offers an ecological niche to avians inhabiting various vertical strata and the unique phenology maximises the function of female trees as females, which is beneficial for seed dispersal and the stability of the community.

Posters

Submission ID: 149

Biodiversity and Conservation of Limestone Areas in Southern Thailand

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Abstract

In southern Thailand, the limestone terrain collects rainfall to form limestone outpourings and wetland forests in the lowlands. These forest floors, filled with clear water, are essential to the region's ecosystem. However, recently, oil palm plantations have been established on the few remaining wetland forests into oil palm plantations, which were previously preserved in southern Thailand.

The study focuses on the conservation of caves and their biodiversity data in southern Thailand, but would like to discuss the conservation of these limestone areas.

3b. Life Below Water

Abstracts

Submission ID: 33

Navigating Sustainability: A Transboundary Socio-Ecological Study of the Brahmaputra River Basin

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Abstract

A river ecosystem, home to diverse biotic and abiotic resources, provides highly valued services benefiting both people and the planet. The transboundary Brahmaputra River originating from the Chemayungdung mountain glacier in Tibet and draining down to the Bay of Bengal Sea in Bangladesh is no different. The river not only sustains livelihood and shared culture along its riparian countries but also nurtures an array of flora and fauna, including the endangered Ganges river dolphin- an indicator of the river's overall health. Cetaceans like dolphins are universally renowned as ecosystem engineers as they play a key role in modifying and maintaining the health and stability of their resident habitats.

Climate-conscious global countries aiming for sustainable development and carbon neutrality are on a constant lookout for low-carbon emission strategies. The transportation sector is one such carbon-heavy industry that is moving towards investments in waterways as they have relatively lower carbon emissions and are cost-effective. Economies with indefinite waterways potential such as the Brahmaputra river basin are experiencing a surge in utilization of their inland waterways. At present, the governments of India and Bangladesh have bilateral ties for trade and transportation over the Brahmaputra River. However, this shift in industry towards sustainability must be considerate of the ecological impacts that it imposes on the river's health and biodiversity. Activities related to inland water transport are evident sources of pollution, habitat loss, degradation, and overexploitation of biodiversity. Besides, the consequences of inland water transport on the dolphins and associated species are avowed.

To assess the existing population of dolphins in the Brahmaputra River, the scope of the study extends from Majuli of Assam to Sirajganj of Bangladesh with three objectives. First, to trace the socio-political-economic dynamics of the inland water transport in India and Bangladesh by enquiring about the inclusivity in decision-making for environmental consideration; second, identifying vulnerable areas in Assam and Bangladesh imposed by inland water transport on the river biodiversity by using modern technological tools; third, suggesting evidence-based mitigation recommendations for policymakers. The objectives will be fulfilled by document analysis supported by qualitative interviews, spatiotemporal mapping and meta-analysis, respectively.

The study is dedicated towards SDG+target 6.6 for restoring the Brahmaputra River and its biodiversity from the impacts of inland water transport and promoting the industry towards strong sustainability. The research contribution of the study is analogous to the conference theme, "Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood", as it supports the sustainable future of inland water transport as an established livelihood provision along the Brahmaputra river while prioritizing safeguards of the future for invaluable biodiversity and associated communities of the region.

Submission ID: 302

Long-Term Monitoring of Trail Degradation in Daisetsuzan National Park, Japan

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Abstract

Trails are essential infrastructure for trekkers/hikers to reach mountain summits and mountain lodges, and trails also play a role in protecting the natural environment from use. However, the location and design of trails are focused on the convenience of walking, and not necessarily on the vulnerability of the natural environment. As a result, trail degradation such as trail erosion have become a problem in many national parks and nature reserves. However, the personnel and budget required for maintenance and management of national parks in Japan are not necessarily sufficient. As a result of the lack of proper management of degraded trails, leading to further degradation caused by heavy rains that have occurred in recent years.

Daisetsuzan National Park has started repairing trails with the help of volunteer trekkers/hikers in 2017. However, due to the limited frequency of trail monitoring in Daisetsuzan National Park, the prioritization of trails for repair and the scientific basis for this prioritization are not adequate.In this study, long-term monitoring using three-dimensional measurement methods such as UAVs and pole photography was conducted from 2014 to 2022 in order to clarify changes and trends in trail degradation. The survey was conducted by dividing the trail into ten sections that pass through flat landform formed by lava flows and pyroclastic deposits called *Hokkai-daira* at an elevation of around 2,060 meters.

The first survey was conducted in 2014. In the first survey in 2014, a large amount of degradation (>200 m^3) was already observed in survey sections on the southeast-facing slope where clayey soil was developed. On the other hand, during the eight years of long-term monitoring from 2014 to 2022, erosion of more than 10 m^3 was observed in study sections covered by pyroclastic flow deposits on the northwest-facing slope, showing a larger amount of erosion than in study sections located on the southeast-facing slope. This indicates that each study section responded differently to heavy rainfall events with daily precipitation exceeding 80 mm that occurred in 2016, 2018 and 2022. The results indicate that identifying changes in erosion rates is important in determining which trails should be repaired. In the sensitive environment of Daisetsuzan National Park, repair work needs to be conducted carefully, and long-term monitoring is essential. However, it is not practical to cover the entire 300 km of trails due to the lack of specialized staff and budget. Therefore, as in the case of repair work, the participation of volunteer trekkers/hikers may play a significant role in acquiring basic data that is essential for decision-making in trail maintenance and management.

This study employed UAVs and pole photos, but iPhone is equipped with Lidar, which makes it relatively easy to acquire three-dimensional data. The establishment of a data collection platform and feedback system will provide value in the contribution to the conservation of the natural environment. Long-term monitoring using three-dimensional data and the cooperation of volunteer trekkers/hikers are essential to enhance the value of national parks and the sustainable use of mountain trails.

3c. Ecosystem Services

Abstracts

Submission ID: 110

Bridging the Gap: Community-Centric Approach to Nature-Based Solutions for Urban Flood Management and Sustainable Development.

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Abstract

In urban contexts, nature-based solutions (NbS) are vital for stormwater management, integrating green infrastructure like constructed/natural wetlands. These mimic natural hydrological processes, reducing urban flooding and improving water quality, offering recreational opportunities and economic savings. A study on Deepor Beel, a Ramsar site and prominent wetland located in the urban landscape of Guwahati city in the Eastern Himalayan Region (EHR). City authorities are actively pursuing the utilization of this wetland as NbS to enhance urban stormwater management. Leveraging the wetland's natural capacity to buffer against flooding while promoting biodiversity conservation and sustainable land management practices concurrently. This approach is perceived as cost-effective, sustainable, and multifunctional, aligning with climate change mitigation and adaptation goals and the broader objectives of sustainable development.

While acknowledging the city authorities' efforts, a consultation meeting with them unveiled a top-down approach lacking input from the local community residing near the wetland. Several research studies on NbS underscore the potential impacts of implementing nature-based solutions (NbS) on local communities and livelihoods, including changes in water availability/quality, land use, and regulatory constraints. Robust stakeholder engagement and adaptive management strategies are essential in addressing these concerns. Against this backdrop, our study assesses the feasibility of utilizing the wetland as an NbS to address urban floods in the city, considering the local context. A mixed-method approach was adopted: hydrological modelling simulated flood events and assessed flood attenuation, followed by stakeholder engagement with communities, agencies, NGOs, and others to gather insights, assess perceptions, and incorporate local knowledge.

The study revealed that untreated stormwater from the city is entering the wetland via natural streams, threatening its health and impacting local livelihoods. Many residents have shifted from traditional agrarian work to low-skill industrial or commercial jobs. The fishing community, in particular, has faces challenges due to declining water quality, resulting in reduced fish catch. Proposed flood interventions that ignore the local context risk worsening water quality and harming both livelihoods and biodiversity. The research underscores the critical importance of involving local communities in flood management decisions to ensure the effectiveness of Nature-based Solutions (NbS) initiatives. While communities acknowledge wetlands as sustainable flood management tools, they stress the necessity of inclusive decision-making processes. The lack of consultation has fueled distrust and conflicts between communities and authorities, resulting in feelings of marginalization among local residents. To promote NbS, especially in mountainous areas, the study advocates for building trust, fostering dialogue with local stakeholders, and considering social and cultural aspects in decision-making. This approach can contribute to achieving various Sustainable Development Goals (SDGs), including poverty reduction, food security, sustainable city, climate resilience, and biodiversity conservation.

Submission ID: 128

Integrating Environmental Impact Assessment and Protected Area Management through Ecosystem Services: Possibilities for Application in Buffer Zones

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Abstract

Protected Areas (PA) are among the main nature conservation strategies available, although anthropic pressure on these areas is a globally identified problem. The way in which the surroundings of PA are used is critical to ensure their protection. Environmental Impact Assessment (EIA) is a useful instrument for anticipating and preventing the impacts of human activities that may result in significant environmental quality degradation. Incorporating Ecosystem Services (ES) into decision-making processes can help improve EIA practices, while addressing issues related to biodiversity loss. Despite the potential of ES approaches to enhance EIA practice and PA management, it is still necessary to study how to integrate them particularly concerning projects located in PA buffer zones (BZ), due to their role in conservation. This research aims to analyze how the concept of ecosystem services can be used to integrate conservation objectives and EIA in BZ of Protected Areas. Semi-structured interviews were carried out with experts and practitioners dealing with analysis of ES within environmental assessments and/ or PA, in order to understand the current frameworks and implementation of this approach across different geographic contexts. Results of a content analysis showed a consensus among participants regarding the importance of ES approach for decision-making processes in BZ, because it can make it easier to communicate impacts and to compare possible land use and land cover alternatives. The majority of participants utilizes software tools to assess ES (e.g., i-Tree, Nature Value Explorer, among others), while others prefer social and participatory approaches for this kind of evaluation. Almost all respondents involved stakeholders in the different phases of their work. Even though some interviewees are aware of the InVEST software, its use is not a common practice. The most relevant ES for the interviewees were water supply and habitat quality. Although ES monitoring is an important aspect for integrating EIA and PA management, few respondents reported the use of this approach over time. While no projects employing the ES approach was reported in the follow-up stage of EIA practice, a more integrated and practical use was observed in PA management. The integration of the ES approach into environmental policies, particularly those concerning PA management and financial incentives like Payment for Ecosystem Services, was noted across several countries, regardless of the continent or economic status. It was concluded that although the ES concept is still rarely applied in integration of both instruments, it holds potential for enhancing conservation efforts in PA surroundings through EIA. This research provides insights into how the ES approach can support and guide EIA in PA buffer zones, that way contributing to protect, restore and promote sustainable use of ecosystems, halt and reverse land degradation and halt biodiversity loss (SDG 15, especially targets 15.1 and 15.9). An ES approach can also be instrumental to reconcile biodiversity protection and sustainable livelihoods, promoting connections between SDG 15 and other SDGs, for example SDG 3 (Good health and well-being) or SDG 6 (Clean water and sanitation).

Submission ID: 291

Climate Regulates the Effect of Abrupt Vegetation Shifts on Soil Moisture on the Loess Plateau, China

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Abstract

To alleviate the social and environmental impacts of soil erosion and land degradation on the Loess Plateau, China has launched many ecological restoration projects. These projects have achieved the goals of increasing carbon stocks and conserving biodiversity, whereas their impacts on soil moisture is ambiguous. Previous studies have focused on the effects of linear greening of vegetation on soil moisture, and they generally hold the contradictory views that revegetation may either increase or decrease soil moisture, because vegetation has the intertwined and opposing effects of increased evapotranspiration causing drying and decreased runoff causing wetting. However, the effects of abrupt vegetation shifts (i.e., the productivity of ecosystem changes dramatically over a short time) on soil moisture remain relatively unclear, and this may result in some threats to soil moisture from extreme restoration measures being overlooked. Furthermore, what exactly determines which effect vegetation has on soil moisture remains to be elucidated. Here, we used the multi-period difference-in-differences method to find that positive abrupt vegetation shifts prevailed (29% for grasslands and 25% for forests) on the Chinese Loess Plateau from 2000 to 2020. To find out the regulators that determining these whether these effects are positive or negative, we used climatic zones to distinguishing the regulatory role of climate. The study found that most of the positive abrupt grassland shifts (89%) favored soil moisture accumulation, whereas positive abrupt forest shifts had positive (51%) impacts on soil moisture in "hot zones" (characterized by higher temperatures and higher solar radiation) but negative impacts (47%) in "wet zones" (characterized as cloudy and rainy). The results show that a full understanding of how abrupt vegetation shifts affect soil moisture is critical for managing ecosystem sustainability. The findings can inform sustainable ecological restoration and water resource management strategies, and reveal areas where revegetation should be prioritised under the background of climate change.

Posters

Submission ID: 237

Ecosystems First: Restoring Ecosystems for Meeting Future Demands for Ecosystem Services

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Abstract

Healthy functioning ecosystems are a prerequisite for creating the potential for flows of ecosystem services (ES) as nature's benefits obtained from ecosystems. Meeting future demands for ES, as intergenerational equity, is fundamental to sustainable development. So too is the ecological restoration (ER) of degraded and destroyed natural ecosystems (SDG 15), now presented as a law in the EU. ER, in this respect, supports employment (livelihood) opportunities.

In Portugal there are limits and challenges to restoring natural ecosystems. Affecting the ER potential for recovering degraded, destroyed natural ecosystems on private land. Despite this, an opportunity exists to assist private landowners with abandoned eucalyptus plantations (AEP) to recover this land naturally, creating the future potential to meet demands for ES. As such, a privately funded project on private land in eastern-central Portugal has undertaken this challenge over an area of approximately 16 hectares.

The methodology, a praxis (practitioner based), heuristic (traditional and low-tech methods), and technology (using cost-effective technologies such as drones) approach the goal of the project is to allow the potential for the endemic (natural) species observed within the AEP to recover without removing (killing) the eucalyptus stumps. A method referred to as 'transitioning', which is part of a PhD study currently being completed by the main author. Transitioning requires the 'thinning' (reduction) of the dominant eucalyptus, opening space and light for the existing natural species. Based on site analyses, this AEP has numerous oak trees. Primarily holm oaks (*Quercus rotundifolia*) with a lower presence of cork oaks (*Q. suber*). The oak trees noted in the AEP were mostly stunted, many presenting a bushy growth form. Showing definite impacts from the faster growing eucalyptus as the canopies of these trees dominate the aerial spaces and access to light.The process decided was for an intervention to reduce (treat) the dominance of the eucalyptus, and a 'wait and see' process to the reaction (recovery) of the oak trees and other natural vegetation noted during the site analysis. 'Wait and see' is an active process involving: 1. the monitoring and evaluation (M&E) of the site using a drone; 2. The random selection of both treated and untreated (control) trees for M&E; 3. Returning to the site to maintain the treatment of the eucalyptus stumps until the site shows clear signs of a recovery trajectory.As far as possible, assessments are done to understand the effects of the changing regional climate, to understand the recovery of natural species, to understand the impacts of the intervention on the local water cycle, soil conditions, and spatial return of biodiversity, a holistic view of the food/energy network that is slowly recovering in this site, as well as the influence of this ER intervention of bordering ecosystems within this location.

The results so far show a positive trend toward the restoration of a novel ecosystem or ecosystems, supporting SDG 15. Furthermore, local employment enhances the sustainability and economic value of local livelihoods.

Track 4 Climate Change and Energy

4a. Effective Response for Energy, Water and Land Use

Abstracts

Submission ID: 42

Examining the Primary Drivers of Carbon Costs in the Chinese Economy

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Abstract

Carbon costs and constraints increasingly impact economic sectors. Carbon costs on the input side are associated with the sector's reliance on fossil fuels. Output-side costs primarily relate to the emissions generated by economic sectors appearing as emission rights and costs related to carbon emission trading systems (Rudnik, 2023).

It is often observed that policies such as fuel and carbon taxes, affecting the input side, are commonly treated separately from climate policies. Insufficient integration in policy efforts may lead to a behavior-impact gap problem at the policy level.

Our research proposes a model to quantify the costs of embodied fossil inputs on the input side and the costs of embodied carbon on the output side. The model is based on an environmentally-extended input-output analysis. Carbon inputs encompass the use of fossil fuels for both energy and non-energy purposes. We illustrate our model with the example of China, as it is heavily reliant on fossil fuels, particularly coal, which constitutes a significant portion of its energy supply. China stands as the world's largest energy consumption deficit economy while ranking as the largest emitter of greenhouse gases (Yang *et al.*, 2023).

Results show that embodied carbon-related inputs within downstream sectors are as much as two or three times greater than direct carbon inputs. The costs of embodied carbon-related inputs exceed the costs of CO_2 emissions across all sectors. The total carbon cost may exert a greater influence on downstream sectors, who are not directly subjected to carbon regulations, than on upstream industries.

Recent climate policy initiatives have primarily focused on addressing carbon emissions (the output side), despite empirical evidence highlighting the substantial impact of the input side. A successful transition towards a low-carbon economy hinges on the existence of high total carbon costs for sectors, which encompasses the sum of both input and output-related costs. For this, the present research offers an integrated carbon accounting approach.

The research is closely related to SDG 7: Affordable and clean energy, sub-target **7.a. and SDG 13: Climate action,** sub-target **13.2.** Results are closely linked to the topic of the ISDRS conference, as by integrated carbon input-carbon output analyses, policymakers can formulate more effective strategies to address the challenges posed by climate change, to contribute to the realizations of SDGs related to climate change and energy policy.

Submission ID: 64

Tradeoffs and Co-Benefits of Hydro-Led Energy Transition in Nepal for Sustainability and Development

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Abstract

With the rapid hydroelectric expansion, Nepal is transitioning from biomass and fossil fuels to renewable energy. The country is eager to pursue its dream of producing abundant hydroelectricity that is often assumed to make it prosperous. However, the rapid hydropower development across Nepal has sparked debate over its implications for society, the economy, and the environment. With the overarching framework of Sustainable Development Goals, this study analyzes tradeoffs and co-benefits of the hydro-led energy transition with other global goals. The study employs a review of the secondary literature and key informant interviews to understand how the renewable energy transition in Nepal can contribute to a just and equitable energy transition that aligns with national development and climate goals. The preliminary analysis suggests that it is crucial to view the energy transition in Nepal as a sociotechnical system as the generation of more electrons may not automatically translate to prosperity. It is crucial to ask critical questions regarding the long-term sustainability of hydroelectric production, transmission, and distribution. While the government has initiated several initiatives to increase internal demand and export surplus energy, the pace has been slow. The larger question is whether the country can manage the surplus energy and who the alternative energy economy is serving. Lessons learned from Nepal regarding concerns about energy access, availability, affordability, and sustainability apply to other countries undergoing similar energy transitions.

Submission ID: 105

Water Sustainability Using Pond-In-Pond (PIP) Wastewater Treatment System for Reuse

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Abstract

The world's freshwater resources are continuously being depleted and water scarcity is already a global issue. The current understanding of our water resources shows that the sustainable limit will be reached by the year 2030 for food production and 2040 for potable water. Several attempts have been made to address this problem, yet few have considered integrating wastewater treatment sites with reuse sites and converting those water resources into a safe alternative to fresh water for agricultural purposes. Wastewater is an easily accessible and abundantly available resource that could meet irrigation needs while conserving freshwater for future generations; yet is highly underutilized, mainly for two reasons – 1) the perceived difficulty of reusing wastewater for agricultural purposes and 2) lack of specific guidelines for designing natural pond systems that adequately predict continuous performance. Also, there exist strong contradictory viewpoints regarding optimal pond dimensions and performance. The best next step thus is to take a different approach in the configuration of the ponds for reuse.

This research provides us with an alternative pond treatment system known as the Pond-In-Pond (PIP) that can be used to treat wastewater sufficiently for reuse. The PIP is a treatment technology where two types of ponds -- anaerobic and aerobic -- are combined into a single pond and consist of a deeper inner pond entirely submerged within the outer pond. The inner deeper section provides anaerobic conditions for more complete degradation of organic matter while the outer pond provides additional treatment through the aerobic process and controls odor. The PIP showed promising performance with an average BOD removal of over 80% throughout the year within a single pond for both municipal and industrial wastes while requiring up to 40% less land area compared to traditional single-process ponds. Results from 2-D models further confirmed that the PIP configuration offers improved flow diversion and higher retention of solids, thus allowing for better and a more consistent level of treatment. The savings in capital costs due to reduced land requirements, savings in operations and maintenance, and consistently higher performance, thus make the PIP a potentially viable and sustainable technology for wastewater treatment, especially for reuse purposes. Further, its simple design and easy operation with revenues from the reclamation of effluent, make it well suited for rural and small communities. Effective pond design and appropriate implementation of the PIP will thus help address the major societal concern of water scarcity with low-cost and effective wastewater treatment for reuse.

This proposed abstract relates to multiple targets within SDG 6 (primarily 6.3, 6.4, and 6.a.), and SDG 2 (mainly 2.3 and 2.4). This abstract is relevant to the topic of the conference as it offers a viable technology for rural and small communities that are widely prevalent in mountainous countries like Nepal where access to centralized treatment systems is limited. This proposed technology also contributes to creating a self-sustained livelihood for such communities as they will be able to manage their waste back into the farms producing foods and generating economic revenues.

Submission ID: 113

Achieving High Integrity Voluntary Climate Action: An Interdisciplinary Review of Principles, Criteria, and Indicators

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Abstract

Non-state actors are increasingly recognized for their pivotal role alongside nation-states in addressing climate change and its impacts. Voluntary climate actions of non-state actors encompass a spectrum of strategies, ranging from mitigating greenhouse gas emissions to enhancing adaptive capacity and fostering climate resilience. Amidst a surge in voluntary climate actions like net-zero pledges and other climate commitments from diverse actors such as businesses, financial institutions, civil societies, and cities, there emerges a pressing need for enhanced scrutiny regarding the integrity of these commitments. Scientific studies, as well as non-scientific reports, indicate that the lack of transparency, accountability, demonstrable permanent impact, and commitment to justice and equity of these voluntary pledges could impede effective and legitimate voluntary climate action.

While voluntary climate actions of non-state actors are integral to achieving the objectives of the Paris Agreement, their proliferation without integrity creates severe challenges, including slowing down and undermining high-integrity commitments by other actors, greenwashing, and creating undue expectations among policy-makers, investors and other stakeholders. Meanwhile, climate action is becoming more urgent everyday. Against this backdrop, the ACHIEVE project endeavours to formulate a comprehensive framework of high-integrity principles for voluntary climate action. Grounded in current climate science, existing research on high-integrity and aligned with the objectives of the Paris Agreement, these principles aim to garner social legitimacy and trust. Here, we present the inter-and transdisciplinary methodology employed in the ACHIEVE project, insights from an interdisciplinary review of relevant principles, criteria and indicators for assessing high integrity and outline the trajectory for future research on high-integrity principles for voluntary climate action.

Submission ID: 182

The Impact of the Covid-19 Pandemic on the Energy Use and Carbon Footprint in Hungary

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Abstract

The present research presents the impacts of the Covid-19 pandemic in Hungary in terms of energy use and the evolution of the sectoral carbon footprint.

After a short literature review on the characteristics, significance and socio-economic consequences of the Covid-19 pandemic, the study first presents the impacts on energy use. For these analyses, annual data on energy use collected by the Hungarian Energy and Utility Regulatory Office were used as the main source.

The results of the analysis show that the indicators in the areas under study mostly show a significant impact only during the period of the pandemic restrictions (or even not there due to various extinguishing effects), but after the lifting of lockdowns, the levels of traffic, consumption and energy consumption have returned to or even exceeded the original levels. For these reasons, the positive impact of the Covid-19 outbreak on energy use can be considered to be at most short term.

To examine the development of the sectoral carbon footprint, national greenhouse gas inventory data was collected and controlled by the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat, the gross value added of the production sectors as a basis for projections was used.

The results of the sectoral carbon footprint analysis show that there are sectors with positive specific emissions trends (e.g., construction-related sectors), but also sectors with diverging or even reverse trends.

The reasons for these changes can be mainly attributed to pandemic prevention measures, economic policies measures, or even simply to weather effects, which may (or may not) have a strengthening effect.

Although the results of the research identify overall short-term pandemic effects on energy use and sectoral carbon footprint trends, the lessons learned from the pandemic through the analyses carried out can be used to shape a more environmentally and economically sustainable future for many sectors.

Submission ID: 243

Techno-Economic Feasiblity of a Solar-Bio-Powered Waste and Wastewater Utilization System for Small Rural Communities

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Abstract

More than 140 billion tons of organic wastes including agricultural and municipal waste streams are produced annually in the world representing an untapped biomass resource. Utilizing these traditional wastes as biomass resources can significantly contribute towards meeting the ever-growing demand for energy while alleviating the negative impact on the environment by reducing greenhouse gas emissions and protecting water resources. However, less than 10% of the waste streams are currently utilized for energy production and other uses. Diverse waste streams, relatively small amounts of individual wastes, logistics and cost of collection, and transportation, and lack of public awareness are the main factors that lead to low utilization of waste streams. Addressing these issues provides a great opportunity for both scientific and industrial communities to make significant contributions to global sustainable development. Due to the complexity of these issues, systems approach is needed to develop new solutions.

The purpose of this study was to implement and evaluate a pilot-scale and closed-loop system that synergistically combines solar thermal collector, anaerobic digester, and post-treatment to simultaneously treat and utilize organic wastes and wastewater. The system utilizes 863 kg of mixed animal and food wastes to generate 263 MJ of renewable energy, produces 28 kg of nitrogen and phosphorus fertilizer, and reclaimed 550 kg of water per day. The net revenue considering electricity and fertilizer was $2,436 annually. The payback period for the system is estimated to be 17.8 years. The implemented system has successfully demonstrated a self-efficient and flexible waste utilization and treatment system. It creates a win-win solution to satisfy the energy needs of rural communities and address environmental concerns of organic waste and wastewater disposal.

Submission ID: 255

Integrated Assessment Modeling and Determinating with SDGs for Linking Future Resilience to an Optimized Climate Risk-, Water- and Drought Management: Comparative Analysis in Lusatia, Spree Forest and Ahr Valley Region, Germany

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Abstract

This research explores strengthening resilience throughout sustainable development, Sustainable Development Goals (SDGs), and an integrated assessment modeling and spatially determinating. Linking future resilience to an optimized climate risk-, water- and drought management means to stress integrative assessment and modeling with the help of comparative analysis in Lusatia, Spree Forest (state of Brandenburg), and Ahr Valley Region (state of Rhineland-Palatinate and North Rhine-Westphalia), Germany, effectively respond for water and land use challenges and can help overcoming the climate crisis and rescuing the SDGs 2030 for sustainable livelihood. Linking sustainable, resilient futures of terrestrial land and ocean requires integeating sectoral aspects of land and water responses into effective instruments, as demonstrated by the self-developed CA(LU)²WA framework for sustainable climate risk (CRM), disaster risk (DRM) and crisis management (CM), including tools likeas the landscape units. Two groundworks advect this research: first the author's innovative theoretical approach for Lusatia, implied Spree Forest Region, possibly for worldwide regions developed, and verbal-argumentative model called "Climate Adaptive Land Use within Landscape Units and Drought and Water Management" (CA(LU)²WA) proactive landscape meta-model; its operational application in the flood-destroyed Ahr Valley Region after flood disaster in mid-July 2021 and simultaneously threatening COVID-19 pandemics. Sustainable development through spatially determining and, operationally implanting SDGs, climate, land, and water resilience, combined with integrated land and environmental systems planning—can enable constructive solutions to climate change challenges. Integrated assessments at the landscape and regional planning scales, guided by SDGs, offer pathways to climate, land, and water-resilient futures for Planet Earth, the ONE. Compiling findings, the research being based on past, long-term theoretical and applied research pillars show that the framework, with its applied instrumentations, such as landscape units and transboundary river basin areas, can synthesize sectoral and integrated aspects of assessment and decision-making into the ideal "prototype region" of Lusatia and inhabited Spree Forest and to override risks and needs parallel in diverse regions, such as Ahr Valley region. The CA(LU)²WA assessment framework, combined with innovative and established methodologies can progressively contribute to overcoming the climate crisis and rescuing the global SDGs 2030 for sustainable livelihoods. It is a high-ranged, sustainable, resilient future-saving, as a flagship, capacity-building initiative, it fosters regional climate, land, and water resilience, and not only in disaster- and pandemic-affected areas like the Ahr Valley, but also in highly industrialized regions like Lusatia. Specific SDGs such as 11 and 13 (via Climate Smart Planning), and 15 and 17 (via Integrated Drought and Water Management), enhance its applicability of diverse regions and assessment fields to gain regional resilience. This research supports interdisciplinary sustainability science and sustainable future processes around multivarious landforms, flat or mountainous land, the same as terrestrial land or ocean.

Submission ID: 274

Risk of Disaster and Riverbank Erosion Linking Vulnerable Community Livelihoods Sustainability in the Ganges - Brahmaputra-Meghna Deltaic Floodplain Region in Bangladesh

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Abstract

The geographic location and the monsoon climate render deltaic floodplains highly vulnerable to natural disasters. Floods and riverbank erosion are a common natural phenomenon in the Ganges-Brahmaputra deltaic region. The climatic change impact is a new threat to food security and livelihoods of the riverine community in the Ganges basin. The Ganges-Brahmaputra-Meghna (GBM) River carries 2.4 billion tons of sediments annually and these sediments settle on the bed of the major rivers and build Char-lands (river bar). The land that has newly emerged in the river channel is called Char-land, there are over 12 million people are living in the islands in Bangladesh. Purba Khas Bandarkhola Mouza of Char-Janajat of Madaripur district in Bangladesh is a unique Char-land located in the Ganges basin area which is an active delta. The community livelihoods and the settlements of char-lands are under threat due to massive floods and riverbank erosion, as a result, the people have to move and relocate their settlements from one place to another within the char-land or outside the char-lands. The climate change impacts are the root cause of massive floods and erosion that extended its negative impacts on rural sustainable development and settlements sustainability issues. The objective of this study is to understand the risks of floods and riverbank erosion impacts on char-land livelihoods and the vulnerability of inhabitants in the Ganges active delta. To develop a comprehensive integrated poverty, livelihoods, and ecosystem management plan for settlement and agricultural stability and livelihood sustainability in the Ganges-Brahmaputra river channels. The study was carried out based on primary and secondary data sources. The results show that the average interval of displacement is every 5 years at the Purba Khas Bandarlhola mouza. The cyclic displacement range is 121 km2 and pull and push factors are influencing the settlement relocation processes. Considering the MDGs, the study also seeks the achievements and success of MDGs of the United Nations at the micro-scale level which is moving to SDGs in the rural areas in Bangladesh. The study found 2 agendas of MDGs which have a meetup and reached the goals before 2030; these are eradicated extreme poverty and hunger, and ensure environmental sustainability. Findings show that the 2 goals are sustainability. Gradually to meet SDGs before 2030 and through future implementation, the process will achieve and meet the 17 SDGs. Therefore, an integrated climate risk and disaster management planning approach and policy framework are urgently needed for the Char-lans' livelihoods and ensure environmental sustainability for the vulnerable communities in the Ganges deltaic fcatchment region in Bangladesh.

Keywords: *Floods, Climate Change, Disasters, Char-land Erosion, Settlement and People Displacement, Livelihoods, Agriculral Sustainability*

Submission ID: 320

Climate Change Impacts on Future Extreme Rainfall: A Study in Nepal, Palestine and Bangladesh.

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Abstract

Frequent occurrence of extreme rainfall events leading to catastrophic floods has been quite evident in the recent years. The IPCC sixth Assessment Report states that the human caused climate change is causing more frequent and extreme events that have led to adverse and irreversible impacts, and will continue to rise in the future. Understanding the risks imposed by the future extreme events is imperative to build resilience and to minimize human and socio-economic losses in the future. Through Tomorrow's Cities project aiming to catalyze a transition from crisis management to multi-hazard risk-informed planning and decision-making for cities in low-and middle-income countries, this study analyzes the changes in future rainfall extremes, and spatial and temporal patterns of extreme rainfall events in Kathmandu Valley (KV) and West Rapti (WR) in Nepal, Nablus in Palestine, and Chittagong and Cox's Bazaar (CB) in Bangladesh.

The study presents a methodology integrating historical extreme rainfall patterns and future projections from Global Climate Models (GCMs) to overcome the limitations of temporal and spatial resolutions of GCMs. It starts with the analysis of historical extreme precipitation, focusing on maximum one-day rainfall (RX1day), and spatial pattern of extreme rainfall events. Future precipitation is obtained from CMIP5 and CMIP6 GCMs for Representative Concentration Pathways-RCP4.5 and RCP8.5, and Shared Socio-economic Pathways-SSP2-4.5 and SSP5-8.5. The GCMs are selected from an envelope type analysis to determine best performing GCMs in the study area or as per the recommendations from literatures. GCM data are bias corrected and statistically downscaled to required spatial and temporal scale. Rainfall frequency analysis, stationary or non-stationary, is performed depending on the Mann Kendall trend test on future RX1day values. The spatial and temporal disaggregation of the rainfall values is done on the basis of historical extreme rainfall event. Satellite based rainfall data is used for the sub-daily precipitation measurements.

From the studies, it was observed that there was up to 50% and 69% increase in RX1day in KV and WR in the future. Maximum RX1day increase of 8% is observed in CB, 18% in Chittagong and 24% in Nablus. Extreme rainfall is expected to be more frequent and intense in the future. For example, 1 in 100-year return period rainfall will be equivalent to 1 in 20 or 25 years and 1 in 25-year return period rainfall for KV and WR, respectively. Up to 60% increase in 1 in 100-year return period rainfall is projected in Nablus. Negative change in future rainfall is also observed in CB, with -6% change in 1 in 100-year return period rainfall. This study allows to quantify frequency and intensity of future rainfall extremes with respect to historical observations, providing crucial information for future urban planning and climate change adaptation strategies. The future rainfall values are valuable inputs for hydrological and hydraulic models to understand the discharge and flood levels in future urban environment, thereby helping in risk informed planning of future cities. This study aligns with SDG#13, target#13.1: strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Full Papers

Submission ID: 140

Dilemma between Solar Panels and Wetland Protection in the Taiwan Energy Transition: A Case Study of Chiayi Budai

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Abstract
This article discusses the the conflict between installing solar panels and protecting wetlands faced in Taiwan's energy transition. It highlights the importance of ecological conservation and ethical considerations in the decision-making process by exploring the government's renewable energy policy, the need to reduce carbon dioxide emissions and the challenges posed by the "demand gap" in renewable energy production. This article uses the DPSIR framework, stakeholder analysis and different perspectives of environmental ethics to discuss the case of Chiayi Budai. The results emphasize the importance of wetland preservation for maintaining the integrity and beauty of the land. It also argues that installing solar panels on wetlands is not an appropriate solution without considering the ecological impact. Furthermore, it highlights the need for stakeholder analysis and public participation in decision-making processes related to energy development and land use. Various stakeholders, including environmental advocacy groups and energy associations, provide insights on balancing renewable energy development and ecological protection. The conclusion discusses the concept of "no net loss" in wetland conservation and the importance of changing people's values to achieve sustainable development.

Keywords: *Renewable Energy Transition, Wetland Conservation, Ecological Impact Assessment, Stakeholder Engagement, No Net Loss*

Introduction

Background

The Taiwanese government has indeed made significant efforts to transition to renewable energy in response to global warming and the need for climate change mitigation. Initiatives such as the "Nonnuclear homeland policy" have been introduced to replace nuclear energy with renewables (Executive Yuan Press Office, 2016). The government has set a target for a 20% renewable energy penetration by 2025 (Tang & Yang, 2019). However, challenges such as the inefficiency of renewable energy production leading to a "demand gap" have emerged, necessitating a careful balance between energy transitions and ensuring adequate power supply (Chen *et al.*, 2014). Despite these efforts, Taiwan has faced power-cut crises during the transition, underscoring the complexities of executing energy transition strategies effectively (Chen *et al.*, 2014).

Dilemma

For fulfilling the demand gap of energy, some solar panels installation sites are on or adjacent to the governmental wetlands for generating power. And the case study sites in Chiayi are located at deserted salt land area closing to Budai Wetland. However, these developing sites are included in IBA (Important Bird Area) for reducing human intervention. On the one hand, solar energy is a kind of renewable energy

which could help Taiwan's energy transition path change from fossil fuels and nuclear power to a sustainable way. On the other hand, the wetland has its essential function in the ecology and environmental systems, such as provide migratory birds habitats, regulate microclimate, purify water, act as a detention pond or carbon sinks (Santangeli *et al.*, 2015). Socially and ethically, decentralized solar power generation can benefit local industries by reducing blackout risks and carbon emissions, albeit at the cost of rising land prices (Santangeli *et al.*, 2015). Consequently, the decision between expanding solar panel infrastructure and protecting wetland ecosystems represents a complex dilemma, requiring thorough evaluation of both ecological and socioeconomic factors.

Literature Review

When discussing controversies related to humans and the environment, perspectives from environmental ethics become crucial. This section will review the three major traditional perspectives of environmental ethics (Attfield, 2012), followed by an exploration of the DPSIR framework.

Perspectives of Environmental Ethics

Environmental ethics encompasses various perspectives such as land ethics, deep ecology, and ecofeminism. These viewpoints challenge traditional anthropocentric ethical frameworks and emphasize the interconnectedness between humans and the environment. By considering the ethical implications of human actions on nature and promoting a more inclusive and caring relationship with the environment, these perspectives contribute significantly to the ongoing dialogue on environmental ethics and sustainability.

Land ethics

Aldo Leopold's Land Ethic, a significant perspective in environmental ethics and conservation biology, asserts that the interdependence among humans, other species, and abiotic entities is central to our ethical obligations (Millstein, 2018). In 'The Land Ethic,' Leopold emphasizes a moral duty to protect the natural world (Cooke *et al.*, 2021). While praised for viewing the environment as an interconnected whole with inherent values, some critique Leopold's conceptualization of ecological systems as organic entities (Sadhukhan, 2022).

Leopold's essay in "A Sand County Almanac" (1949) presents a systematic eco-centric ethical framework (Eba, 2020). He states, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." This principle underscores the importance of maintaining ecological overall value and balance (ecological holism). Consequently, wetland protection aligns with this ethic by preserving the land's integrity, stability, and beauty, viewing humans as land citizens rather than conquerors. Thus, land ethics prioritize the “ecosystem as a whole”, advocating for the preservation of its completeness, stability, and beauty.

Deep ecology

Deep ecology identifies the root cause of the environmental crisis as the mainstream industrial philosophy, which emphasizes individualism and separation from nature. This philosophy views humans

as independent from natural determinism due to their mind, free will, and soul. In contrast, deep ecology's "Physical Holistic Theory" posits that humans are integral parts of nature and cannot exist independently of it. Arne Naess argues that this separation is flawed and advocates for a humble approach to the environment, warning that human interference leads to unpredictable, long-term ecological changes that are often irreversible. He criticizes conservation biology for its limited understanding and lack of holistic, long-term thinking.

Deep ecology emphasizes the intrinsic value of all living beings and the importance of ecological and cultural diversity (Akamani, 2020). It highlights the interconnectedness between individuals and their surroundings, advocating for a reciprocal relationship (McMahan, 2009). This perspective integrates ethical and political dimensions (Luke, 2002) and suggests a sustainable development framework that prioritizes both social and ecological well-being through adaptive governance (Akamani, 2019).

Naess's deep ecology teaches that "quick-fix" technological solutions to environmental problems are inadequate, as they ignore the deeper epistemological and philosophical roots of these issues. This perspective is crucial for Taiwan's energy transition towards a low-carbon industry through sustainable energy investments. However, installing solar panels on wetlands is problematic due to its significant ecological impact and potential harm to endangered species. If installations are necessary, efforts should focus on minimizing environmental impact by promoting energy-saving policies and improving energy efficiency.

Ecofeminism

Ecofeminism intertwines feminist and environmental concerns, highlighting the interconnectedness between the oppression of women and the exploitation of the environment (Brookes & Chałupnik, 2022). This perspective calls for a holistic understanding of environmental issues, emphasizing the interdependence of all living beings (Tiwari, 2023). Ecofeminism critiques the parallels between women's subjugation and nature's exploitation, advocating for a more inclusive and caring relationship with both (Brookes & Chałupnik, 2022). Scholars apply ecofeminist principles across disciplines to address environmental challenges and promote sustainability through gendered and environmental justice lenses (Stephenson, 2023; Kennedy & Dzialo, 2015).

Central to ecofeminism is the belief that environmental issues should be approached with "care" and "relationship" rather than abstract and rational ethics. This perspective values concrete, emotional actions and emphasizes caring for both wild places and human societies. Ecofeminists argue that addressing unfair and unreasonable phenomena fosters virtue in individuals.

Therefore, installing solar panels on wetlands represents the domination and exploitation of nature. Such actions should not proceed without considering relational impacts and conducting thorough environmental impact assessments.

DPSIR Framework

The DPSIR framework, developed in the late 1990s, serves as a tool for reporting and analyzing environmental problems on scales ranging from global systems to localized watersheds. Since its

inception, international organizations have adopted DPSIR to evaluate sustainable development initiatives, aiming to better understand and overcome barriers to sustainability. (Carr *et al.*, 2007)

The DPSIR framework has transitioned from primarily being expert-driven to now serving as a heuristic device for stakeholder engagement and understanding (Atkins *et al.*, 2011). Widely used for environmental assessment, it is a valuable tool for analyzing complex social-economic-environmental issues (Abalansa *et al.*, 2020). The framework aids in structuring information for decision-making and has been applied in various contexts such as ecosystem services assessment (Rounsevell *et al.*, 2010), water governance (Vannevel, 2018), and vulnerability assessments (Anandhi *et al.*, 2020). By integrating various disciplines, the DPSIR framework provides a comprehensive review and alternative decisions for environmental challenges (Graham, 2023). It is a valuable tool for analyzing cause-effect relationships and linking scientific findings with real-world issues (Swangjang & Kornpiphat, 2021).

Methodology

In this study, multiple research methodologies were employed, including documentary analysis, the DPSIR framework, stakeholder analysis, and environmental analysis of site selection. Initially, the author summarizes different environmental ethics to identify how various perspectives address the chosen dilemma. The study then applies the DPSIR framework to highlight essential elements in the case study sites. Stakeholder opinions are gathered for analysis, and cost-benefit analysis and technology assessment results help confirm or refute arguments within the dilemma. Finally, the study proposes five recommendations based on environmental regulations and principles, discussing different strategies for governments or decision-makers and comparing the advantages and disadvantages of each solution.

- Documentary Analysis: This involves reviewing and analyzing existing literature, reports, and documents to understand the historical context, current policies, and perspectives on the conflict between renewable energy development and ecological conservation.
- DPSIR Framework: Used as a decision-support tool, the DPSIR (Driving forces, Pressures, State, Impacts, and Responses) framework structures the analysis of environmental problems. It helps identify key elements and their interrelationships, providing a systematic approach to assess driving forces, pressures, and the current state of ecosystems, impacts, and possible responses to mitigate negative outcomes.
- Stakeholder Analysis: This method gathers and analyzes the opinions and concerns of various stakeholders, including government agencies, academia, civil associations, and local communities. It is crucial for understanding different perspectives, identifying potential conflicts, and finding balanced solutions that consider both renewable energy development and ecological protection.
- Environmental Analysis of Site Selection: This analysis evaluates the environmental suitability of potential sites for solar panel installation. It assesses ecological characteristics, such as the importance of bird habitats, and the potential impacts of solar panel installation on these ecosystems. The analysis includes cost-benefit analysis, which helps decision-makers weigh economic implications and provides a structured framework for evaluating trade-offs between different options. This ensures resources are allocated efficiently and decisions are based on a thorough assessment of costs and benefits, aiming to minimize ecological disruption.

By integrating these methodologies, the study provides a comprehensive evaluation of the dilemma between solar energy development and wetland conservation, offering insights and recommendations for sustainable decision-making.

Results

DPSIR Framework

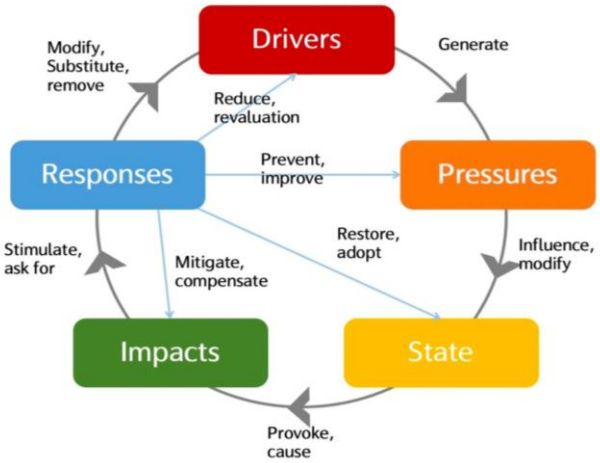


Figure 1. Overview of DPSIR Framework

Driving forces (D). Driving forces are "needs." Three main types are:

- Individual or primary needs: electricity for essential daily use, like lightening, air conditioning.
- Secondary needs: a) Energy for higher living conditions (i.e., unessential appliances) b) Security of power supply: secure energy supply after the decommissioning of the nuclear power plants in 2025
- Macroeconomic needs: industry production, jobs, installation space. a) Infrastructure and investment in the remote area (that the local government strongly emphasized) b) New industry that supported by the policies that are possibly rejuvenating the elderly communities in remote areas

Pressures (P). Pressures are defined as results of meeting a need.

- World carbon dioxide balance: Wetland can be a carbon sink but solar energy also a sustainable way to generate electricity
- Climate change / global warming: Pursuing sustainable development with stable, affordable, relatively clean energy for both individuals and businesses that tend to reduce GHG emission under the Taiwan Energy Transition
- Landscape changes: Keep the wild land wild for the existing ecosystem, or rent it out for solar energy installation, there might be some inappropriate vegetation transplanting to fulfill the "landscape plan" but would crush the native species
- Air pollution: Wetlands' purify function loss and change of energy generating proportion
- Water pollution: Cleaning water discharged into the nearby waterways might cause some unexpected impacts

State (S). State is a snapshot (the present situation). Quality of various environmental compartments and ecosystems local and globally (air, water, soil), including human health and wellbeing.

- Microclimate changes: Temperature increases rapidly and more sensitive.
- Sensitive species endangered: The population of Black-faced Spoonbills (= Platalea minor, 黑面琵鷺) are being threatened, and the distribution of phytoplankton, zooplankton, benthic organism, mollusk, fishes and birds would change
- Change of land use type: The area of the wetland is altered to the solar photovoltaic installation, starting desertification, the water flow being redirected, the vegetation will be changed, and the albedo might differ (raw land vs. solar panels + plants)

Impacts (I). Impact means "changes" in the state as a result of meeting a need.

a) On Environment/ Ecosystem:
   - Carbon emissions changes o Large scale desertification o Decrease of ecosystem service
   - Capability against floods of resilience decrease

b) On Animals:
   - Loss of unique species, like Black-faced Spoonbills and Kentish Plovers (東方環頸鴴) ○ Original species were deported from their land: The possible turbulence may cause it to the nearby wetland ecosystem which will diminish the habitat of the preserved

c) On Human and Society:
   - Land price increase and infrastructure expanded
   - The balance between human activities (i.e., farming and fishery) and wild lives will be broken; thus, some disease might be triggered and spread. Possibly bringing negative impact on human health in the long-term
   - The tourism of sightseeing will decrease but might bring some job opportunities to the local communities
   - A case for further discussion that the local communities, NGOs, the local or central government may reassess and discuss the appropriateness of renewable energy installation

Responses (R). Defined as actions that policy-makers, society and others can take to address an undesired impact.

a. For Driving force
   Reduce energy usage demand:
   - Promote energy-saving policies and improve energy efficiency in the country

   Revaluation:
   - The national energy demand and supply
   - Alternative energy supply (i.e., wind power)
   - Energy proportion, industry transfer from heavy-load manufacturing to carbonfree
   - Energy transition strategy: How to be green? Why in such an emergency process?

b. For Pressure
   Prevent
   - Conflict of land use: Through national and regional planning, including different departments advised sort of Policy EIA

- The regulation amendment and regulation enforcement, details will explain in the following discussion.
- Prevent pollutions by developing a detailed regulatory plan and assessment process. o Improve
- The decision-making process of sites selection and public participation.
- Consideration of other alternatives and Taiwan's NDC should include careful due diligence.

c. For States
Restore the habitat of sensitive/endangered species.
   - Environmental Impact Assessment: the background research of the existing environment
   - Adopt environment/ecological-friendly engineering or best available control technology (BACT)

d. For Impacts
Recycling mechanism
Communication and education
   a. Data collection and reporting to the authorities / open for public supervision o Notification system for the emergent events, like disaster scenario simulation

Stakeholder Analysis

Development of renewable energy plays a vital role in the energy transition. However, the establishment of renewable energy such as wind turbines and photovoltaics is often accompanied by doubts about ecological conservation, the impact of residents' living rights, and livelihoods. Is the dilemma between photovoltaics and wetland protection a sum-zero game? Stakeholder analysis can help the study to clarify the answer from different perspectives. This paragraph contains extensive citations from publicly available reports by the Environmental Information Center, Civil Media, Up Media, and other named sources. Therefore, no anonymization of the sources is necessary.

From government

Wei-Yi Wu, head of the Energy Technology Group in the Bureau of Energy, pointed out that both Japan and Germany have experience in salt fields photovoltaics, and through eco-design, they have the opportunity to improve the habitat of animals and plants and even create new habitats. For example, birds inhabit the floating solar photovoltaics on the stagnation ponds in Pingtung, southern Taiwan.

Chi-Chung Chen, the chairman of the Agriculture Committee, said that if there is no scientific basis for the solar panels on the wetlands, the relevant plans should be suspended. If there is no relevant fundamental research, the risks will be too high. Besides, the Bureau of Energy, Construction and Planning Agency, and Forestry Bureau should conduct cross-departmental discussions with civil society organizations and try to understand different case studies to find ways to create a win-win situation. He also explains that the heavy metal pollution and the identification of agricultural land that cannot be used for cultivation where can alter to be used in setting up photovoltaic panels.

From academia

Ben-Jei Tsuang, a professor of the Department of Environmental Engineering at National Chung Hsing University, suggested that large-area solar panels should still be given priority in sites that are

contaminated with heavy metals and are not suitable for agricultural farming. At present, the configuration of installation sites seems to be too concentrated on the southwest coast. Before the feeders become more stabilize, the development of renewable energy such as solar energy should be evenly distributed in different regions to avoid excessive concentration and reduce the pressure on power dispatching.

"If Taiwanese people consider it, they have more energy options. Hui-Chen Lin questioned why Taiwan, with its excellent geothermal resources, hasn't utilized them. Despite relying on imports, Taiwan's electricity prices are the second lowest globally. Energy conservation efforts have been ongoing for years, but results are lacking. There's significant room for improvement, and many aspects of the energy policy remain unclear."

Hui-Chen Lin, a professor of the Department of Life Science at Tunghai University, who is the host of the photovoltaic eco-foundation survey program at the Chiayi Budai, questioned why it is necessary to install the PV panels in a place with abundant bird habitats. "Even in the wasteland, there is value as a wasteland," she said. Speaking of energy options, she bluntly said that Taiwan is in the earthquake zone, and there is nowhere to go for nuclear waste. As a result, there is no condition to develop nuclear energy. She contends that there is room for improvement in both coal and natural gas, but these energy sources are limited. Solar energy is a relatively easy way to go, Taiwan has the technology, and these technologies are still moving forward.

From civil association

Xuan-Fu Guo, Chairman of the Solar Power System Association, said that in addition to taking into account the bird protection and wetland ecology, salt fields could not shield against typhoons owing to the salt is easy to wear. The commercial guild position suggests that the use of fallow farmland should be used to develop photovoltaic panels.

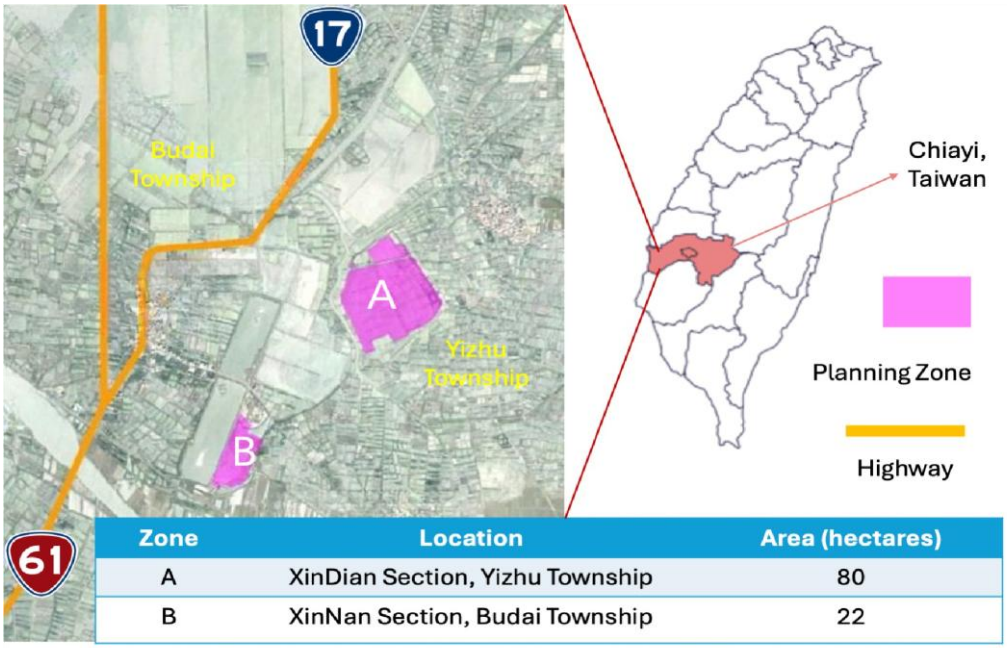
The Chinese Bird Association advocates that the planning and decision-making process should be transparent and use scientific methods to monitor, avoid ecologically sensitive sites to balance between green energy development and ecological protection. For habitats that do not have sufficient scientific research, conservative attitudes should be adopted, and third parties should be appointed for detailed monitoring before evaluation rather than develop in a rush way. The representer of Chinese Bird Association said: "Green energy development is an important policy to slow global warming and climate change. We fully support it, but we should not blindly sacrifice the ecological environment shared by the people of Taiwan."

Han-Lin Li, director of the Citizen of the Earth (CET), a not-for-profit environmental justice advocacy organization in Taiwan, pointed out that installation PV systems on wetlands are considered solutions in some way. Taking PV systems on fishing farms as an example, fishers use fishing farms to make a living and create an environment with water and food. PV systems on fishing farms not only more attractive to birds but also useful for renewable energy development. The point is not to use the environmental resources excessively so that the damage would be irreversible. Speaking of the example Chiayi Budai, he believes that information disclosure and public participation opportunities are still insufficient. Although

the government communicated with the Chinese Bird Association and local people during the preliminary planning, many of them were not official channels, and many opinions and information were not open enough. He suggested that the government should not be anxious, first construct a system of social participation step by step. Otherwise, several negative cases will lose the support of the society.

Environmental Analysis of Site Selection

In this part, this study tries to answer the question: How the installation sites in Budai being chosen?



Zone	Location	Area (hectares)
A	XinDian Section, Yizhu Township	80
B	XinNan Section, Budai Township	22

Figure 2. Priority PV Installation Demonstration Zone

This area of Chiayi Budai has initially been a waste salt field. Due to the decline of the salt industry, there was less human interference, and it became a migratory bird habitat. Firstly, from the 4,314 hectares of state-owned salt fields, the Bureau of Energy first excluded state-level important wetlands, ecologically sensitive areas, and wild bird hotspots. After communicated with the National Commission on Agriculture (COA), bird conservation associations, and local people, the Bureau of Energy decided to set a 374 hectare "Photovoltaic Demonstration Zone" in Budai, Chiayi. However, there is considerable debate about the selected 374-hectare area, which is actually within the scope of the "Important Wild Birds Area (IBA)" recognized by the BirdLife International. Chinese Wild Bird Federation (CWBF) claim that the selected 374-hectare area should be planned to be included in the essential national wetlands and protected by the country. Secondly, Associate Professor Yih-Tsong Ueng, who affiliated with Kun Shan University, pointed out that the state of birds in salt fields might be more abundant than the critical wetlands in the country because the waterfowl runs along with the water level. Changes in water levels can also affect waterfowl habitats. Different water levels also have hot spots of different species. It is not easy to rule out the so-called "bird habitat hotspots" in the selected area. As a result, Endemic Species Research Institutes conducted a series of research on birds' habitat within the wetland ecology (TEIA, 2019).

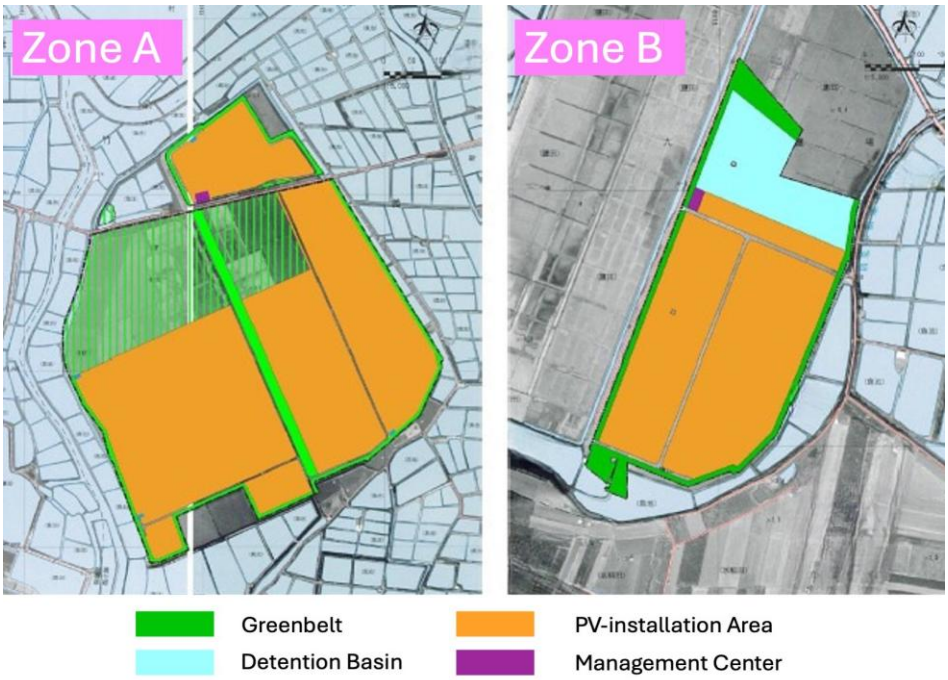


Figure 3. Layout Map of Planning Zones

Finally, considered the direction of the water flow, the Bureau of Energy selected 80 hectares of zone eight and 22 hectares of zone nine as demonstration areas. In 2017, the bid was conducted by Vena Energy (韋能能源) and Sinogreenergy (天泰能源). The final bids of two Energy Company agreed to vacate 30% of the land in the tender area as an ecological protection zone and continue ecological monitoring from the pre-operational period to the 20-year operation period. Sinogreenergy has included all 243 hectares of land in zone nine into the environmental survey, which is 11 times the tender bid. In the bid evaluation process, the manufacturer also agreed on the specific actions with the environmentalfriendly and ecological way such as no cement pavement; do not fill the soil to keep the original flood detention function; sites fences are placed deep into the ground to prevent wild dogs from eating eggs or young birds.

Discussion and Recommendation

Can photoelectric and wetlands coexist?

Sinogreenergy confidently believes that can find the answer through environmental-friendly construction and community cooperation. Sinogreenergy found a team, who does not agree with wetland photoelectric but hopes to use the research to find the truth, to conduct a research will last for 21 years and will be Taiwan's first systematic and comprehensive record of salt fields photoelectric, witnessing the environmental changes of salt fields photoelectric in Taiwan.

Sinogreenergy bid the 22-hectare area on the south side of the salt field in zone nine. In addition to committing to ecological surveys before, during the construction phase and at least 21 years of operation, Sinogreenergy has more than 243 hectares of ecological surveys in all zone nine, which is 11 times larger than the case. Although the 22 hectares are not within the scope of critical national wetlands, they are located in the "Important Wild Birds Habitat (IBA)" designated by the BirdLife International. After the news of wetland photoelectric was exposed, there caused a lot of opposing arguments. In this regard, when the development area was not finalized in 2017, Chairman of Sinogreenergy went to the local forum presenting the idea of wetlands, photoelectric, and coexistence with local communities.

He said that solar panels have monitoring equipment that can protect the place and reduce the situation of dumping waste; or combine environmental monitoring such as video, soil and water quality to make bird ecological observations, breaking through the limitations of human resources shortage in the past. The statement of Sinogreenergy at that time became a commitment to the locals. He also elaborates on the case of Guangcai Wetland in Pingtung by pointing out that the local photovoltaic panels have been covered for seven years. In that case, the fish ecology maintained well, and the redcrowned bird, small egrets, and other birds are still inhabited. So, he thinks that photoelectric and wetlands can coexist.

Besides, he believes that different methods can improve the environmental impact. He has proposed to replace piling with watering to reduce noise. However, this involves the review that has been passed and cannot be decided by the manufacturer.

Hui-Chen Lin, a professor of the Department of Life Science at Tunghai University, who is the host of the photovoltaic eco-foundation survey program, found that although there were wetland photoelectric cases in the world, there were very few research reports, and the officially published academic literature was lacking. Whether it is determined that birds are afraid of photoelectric or how the ecology system changes within solar panels, there is a lack of long-term and quantitative research. How long does it take to respond to ecological functions? There are no answers to many questions now. After a few thoughts, Hui-Chen Lin took over this task and has accumulated more than one year of background information. Environmental survey projects include ecology, hydrology, soil, and water quality. The ecological part includes birds, fish, crabs, snails, zooplankton, and vascular plants.

Revaluation the Energy Demand

For reducing the driving force, the first thing is to evaluate the energy demand and supply at the national level. Secondly, focus on reducing energy usage demand by promoting energy-saving policies and improve energy efficiency in the country. Like professor Hui-Chen Lin questioned: "Taiwan's energy depends on imports, why is the electricity price the second lowest in the world?" The main reason is there is no politicians have guts to raise the electricity price to a reasonable number in Taiwan, which must kill their career and lost the votes. The advantages are Taiwan can rethink the path of how different energy proportion could let the industry transfer from heavy-load manufacturing to carbon-free. Are there any better alternative options for different scenarios? Besides that, the disadvantage will be that Taiwan cannot put into practice the NDC on time.

Improve the Public Participation

Speaking of the Environmental Impact Assessment process in Taiwan, some local government would only consider the experts' opinions. However, there are other stakeholders need to engage in the discussion like the landlord, bird associations, factory owner and so on. When the conflict of land use comes up, through the national and regional planning, including different departments advised sort of Policy EIA, the public participation becomes more important. In Budai's case, the author gathered different perspectives from different stakeholders, which can help to revise the regulation amendment and regulation enforcement. More than that it also helps to prevent pollutions by developing a detailed regulatory plan and assessment process.

Alternative: Rooftop PV Systems

Taiwan government pushes solar energy, which is expected to reach 20 GW in 2025. However, solar energy development requires a large amount of land, and wetland photovoltaics is controversial. The government has turned to the less controversial sites, like salt fields and the subsidence area to set up a solar energy zone. Some scholars suggested that there are many buildings in Taiwan, and it should be developed towards rooftop solar energy instead of occupying precious land resources.

Chong-Xian Chen, a select committee in the Bureau of Energy, agrees that rooftop solar energy does have more benefits, but because of the excessive number of illegal add-on rooftops, the available roof is greatly restricted. The Construction Department is studying the relaxation of the regulations to take into account the safety of the buildings and the probability of rooftop PV systems.

Ecological Compensation

The operation surface of ecological compensation is to evaluate the efficiency of the project. Salt fields are all responsible for solar photovoltaic, and there must be some gains and losses. Also, wetland conservation will have pros and cons. How much power is generated, how much economic benefits people have, how much damage to birds, landscapes, water environment, and what are the alternative measures? In which the public can get a compromise, citizens can know how much to develop and how much to protect. After assessing the ecology compensation plan, the economy can develop without derogation.

According to the "Wetland Conservation Law (WCL)" and the "Implementation Measures for Impact Mitigation and Ecological Compensation (IMIMEC)", the development and utilization of critical wetlands and their surrounding areas are listed. The measures for pre-development ecological compensation may include the following:

- Biomass compensation: The development unit can develop, but the competent authority should set the bio-compensation ratio and the re-education standard. The development unit must manage the habitat environment, keep the biomass unchanged, or even reach a higher quantity before it can be developed.
- Compensation in different places: If the pre-development land assessment fails to maintain biomass, it can be compensated in different places, considering habitat connectivity, ecological benefits, water resources relevance, and selecting location for re-education.

- When national-level important wetlands are affected by development and ecological compensation is provided in or adjacent to the development and utilization behavior areas, the area ratio must be compensated by 1:2 or 1:3. The rehabilitation base is public land, and the compensation ratio is double.
- It can be used to improve the wetland diversity and water quality, engage in scientific research, environmental education, management, and maintenance of wetlands, and have detailed wetland impact fees and compensation calculation formulas.

Aim for no Net Loss of Wetlands

"No net loss" is a government policy to achieve no net loss of wetland area and/or ecological character at a given geographical scale (often national). Wetland impacts may be permitted, but compensation (through restoration or creation) is needed to counterbalance these, not necessarily site-by-site but for the total wetland resource. A "no net loss" policy may be limited to a particular program, subset of wetlands or jurisdiction. It may be one way of implementing wise use. However, as yet there are no studies on whether Contracting Parties with such policies have achieved this with respect to wetland functions rather than simply wetland area. Further monitoring of effectiveness is required. A "no net loss" policy should not be implemented in a way that undermines the primary imperative to avoid impacts to natural wetlands (Horwitz *et al.*, 2012). In consequence, the Ramsar Convention encourages a stronger "no loss" approach. The no net loss concept has been adopted in biodiversity offsets in more than 80 countries, although often only vaguely defined (Maron *et al.*, 2018).

Conclusion

In recent years, human beings have realized that damage to the environment will endanger human survival and are committed to maintaining the stability and balance of the ecosystem on the planet to seek "sustainable development" of mankind. But to completely solve environmental problems, we must first change people's "values" or "views." From the different perspectives (anthropocentrism, life center ethics, and ecological center ethics) on "sustainable development", we can find that although different environmental ethics have different "ethical meaning and characteristics" also derive different "reasons for supporting sustainable development", but we can all get the theoretical basis of "human beings live in harmony with nature." These are rational world views that can make human beings live forever on earth. They can also prevent other lives from being extinct, and maintain the stability, integrity, and beauty of the green circle, and achieve the goal of sustainable development for all.

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PURE a Digital Platform: Unveiling Nepal's Potential Renewable Energy Demand in Irrigation for Informed Decision Support

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Abstract

In Nepal, 60% of agricultural land lacks year-round irrigation, posing significant challenges to food security and farmer livelihoods. Renewable energy is pivotal in addressing these irrigation needs, particularly given Nepal's potential for a 100% renewable energy grid. The PURE (Productive Use of Renewable Energy) platform offers a transformative solution, integrating satellite imagery, field data and advanced modelling to bridge data gaps. This web-based platform allows userguided inputs to select various dataset layers, facilitating comprehensive suitability analysis for irrigation. By assessing land cover, terrain, surface water availability, and more, PURE identifies suitable irrigable areas and estimates crop water requirements and power demands. The platform's assessment estimates a renewable energy demand potential of 800 to 1300 MW for irrigation needs. Validated through expert consultations, PURE supports decision-making for government officials, researchers, and practitioners. Therefore, a web-based platform like PURE is important to enhance food security and farmer livelihoods by providing necessary information in lift irrigation for informed decision support.

Introduction

Nepali farmers face significant challenges due to shifting weather patterns and inadequate irrigation infrastructure, which severely impact agricultural productivity and livelihoods. Statistics reveal stark realities that 60% of the total agricultural land in Nepal lacks year-round irrigation access, and a staggering 87% of hill agriculture land remains without irrigation facilities. Moreover, it is estimated that over 0.7 million farm holdings do not have access to year-round irrigation [NSO, 2023]. These deficiencies hamper the ability to cultivate food effectively, threatening both food security and economic sustainability.

Addressing these challenges demands concerted efforts to enhance irrigation infrastructure and adopt innovative, climate-resilient farming practices supported by renewable energy solutions. Despite the pressing need, the agriculture sector consumes less than 1% of the total national energy consumption. Furthermore, 85% of the energy used in the agriculture sector is derived from fossil fuels [WECS, 2023]. This imbalance highlights a significant gap and underscores the urgent need for interventions. Renewable energy for irrigation can serve as a potential climate mitigation and adaptation solution. Such interventions can improve agricultural productivity, enhance resilience, and secure the livelihoods of Nepalese farmers amid increasingly unpredictable climatic conditions.

Nepal's diverse topography, river and tributary networks and agricultural landscape offer immense potential for using surface water for irrigation through renewable energy sources. The opportunity lies in harnessing this potential to develop sustainable solutions that can address the current irrigation challenges. The integration of renewable energy into the agriculture sector is crucial not only for bolstering

agricultural resilience but also for ensuring reliable access to irrigation, particularly in the hills and mountains where water is required to be lifted.

To fill this gap and capitalise on the opportunity, the Productive Use of Renewable Energy (PURE[1]) platform by ICIMOD has been developed. This platform aims to address critical questions related to the potential of lift irrigation from surface water, including energy requirements, investment estimates, and projected benefits. It also provides information on whether the lift irrigation power source can be grid-based or off-grid, depending on utility distribution proximity.

The PURE Platform is an innovative digital platform specifically designed to revolutionise renewable energy demand planning for irrigation in Nepal, especially in the mountain regions. It harnesses the power of satellite imagery and advanced modelling to uncover market opportunities for renewable energy integration, particularly in irrigation, addressing critical information needs.

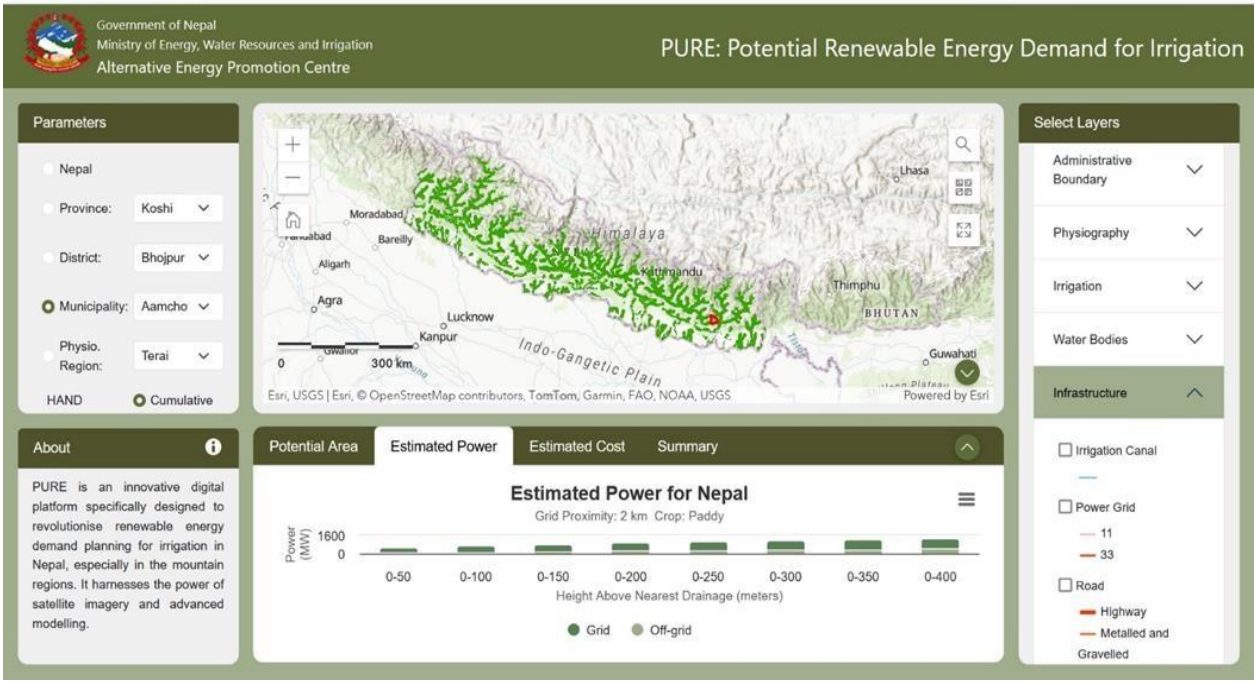

Figure 1. PURE platform

Figure 1 shows the user interface of the PURE platform. It enables user-guided inputs (left side of Figure 1), and selection of various dataset layers (right side of Figure 1) encompassing administrative boundaries, physiographic zones, transmission lines, river networks, canals, road access, and more. These layers are seamlessly integrated to visualise potential renewable energy demand for irrigation (centre of Figure 1) and cost estimations across national, provincial, district and municipality levels through clear graphics and tables (bottom of Figure 1). By offering insights into renewable energy demand planning for lift irrigation, it can facilitate informed decision support for governments, development partners, private sectors, practitioners, researchers, academics and relevant stakeholders.

Literature Review

Utilising complementary technologies such as remote sensing in conjunction with Geographic Information Systems (GIS) has proven essential for crop monitoring and implementing precision management techniques to increase agricultural productivity [Ghosh & Kumpatla, 2022]. By properly matching the supply and demand for energy, the spatial mapping of energy resource availability and demand would support integrated energy planning [Ramachandra & Shruti, 2007]. Since web-based platforms can combine and present complicated data in an easily comprehensive way, they have become indispensable tools in many fields, such as agricultural and water resource management [Amado *et al.*, 2018]. These platforms can potentially be extremely beneficial in planning and decision-making when it comes to visualising the potential area for lift irrigation, accompanying energy needs, and associated costs. For the identification of potential land for lift irrigation, suitability analysis or multi-criteria decision analysis can be the most appropriate and effective method [Tesfaye & Defersha, 2024].

Despite the advancements in technology and methodologies for energy planning and agricultural management, there is a significant gap in the literature regarding the specific energy demands of the agricultural sector in Nepal. No comprehensive studies have systematically mapped out the energy needs for irrigation or evaluated the potential for integrating renewable energy sources to meet these demands. This lack of data and analysis hampers effective planning and policy formulation to support the agricultural sector. The PURE (Productive Use of Renewable Energy) platform was developed to address this critical gap by providing a detailed analysis of the renewable energy demand for lift irrigation, enabling better decision-making and resource allocation to enhance agricultural productivity and sustainability in Nepal.

Approach

The PURE platform comprises a comprehensive methodological framework for the estimation of power demand for lift irrigation in Nepal. The general workflow of the PURE platform consists of Suitability analysis, Crop water requirement, Power demand and Cost estimation as shown in Figure 2. The process commences with an extensive suitability analysis, wherein several factors including land cover, digital terrain model, slope, soil texture, soil depth, and surface water supply are assessed to find regions that are conducive to irrigation. The inventory of inputs from these parameters has been carried out using remote sensing and GIS techniques. Afterwards, the platform calculates Crop Water Requirements by evaluating the demands of the most cultivated crops, offering an approximation for irrigation water needs. Power requirement estimation follows, calculating the power demand for lifting water based on the identified potential unirrigated areas and crop water requirements. This methodology ensures a thorough analysis of suitable irrigable areas, power demands, and cost estimations, presented through an interactive web-user interface to facilitate decision support for effectively planning renewable energy-powered irrigation in Nepal. The platform's results are validated through expert consultations and workshops.

Figure 2. General workflow of the PURE platform

Suitability Analysis

The identification of suitable land for lift irrigation is an important fundamental task in estimating energy demand and cost estimation. GIS frequently employ suitability analysis for spatial data, which is a method to assess if a certain location is suitable for a given purpose or use. It entails looking for places or regions that have several distinct characteristics. Often, the output of a suitability study is a suitability map that indicates which regions are appropriate for a certain usage. In this study, suitability analysis was performed to identify the potential land for lift irrigation within cultivable land. The methodological framework illustrates the overall workflow for the estimation of potential areas for lift irrigation shown in Figure 3.

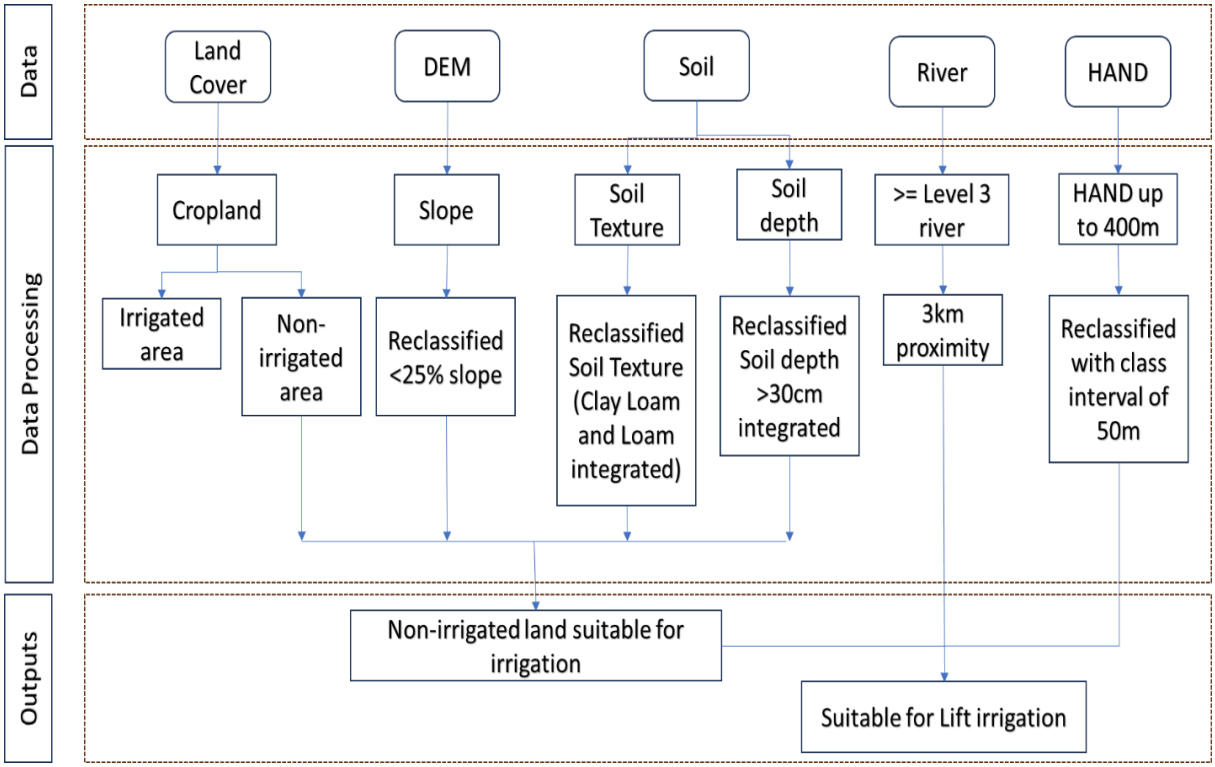

Figure 3. Methodology for identifying the suitable land for lift irrigation

The detailed description of these steps is explained below:

Acquisition and Processing of Data

The physical parameters affecting the suitability of potential land for lift irrigation as shown in Table 1 were obtained and processed for the study. The data was obtained from secondary sources hence, the limitations and uncertainties that exist in the dataset are also the limitations of this study. The combined effect of these components imposes the degree of appropriateness and assists in determining the extent to which the land is suitable for lift irrigation.

A. Data

Detailed descriptions and sources of data used in the PURE platform are provided in Table 1.

Table 1. Data, sources and descriptions

Data	Sources	Descriptions
Land cover	ICIMOD RDS, 2024	Raster Data: consists of 11 classes: Forest, other wooded land, Grassland, Cropland,
		Bare soil, Bare rock, Snow, Glacier, Water body, Riverbed, and Built-up area
Irrigated area	DWRI, 2024	Polygonal Shapefile
Digital Elevation Model (DEM)	NASA Shuttle Radar Topography Mission [SRTM, 2024]	30 m resolution
Grid (Transmission Lines)	Nepal Electricity Authority (NEA)	11 kV
River networks	Hydro SHEDS [Geoglows, 2024; Hydrosets, 2024]	River network of Nepal (River order level 3 or above)
HAND (Height Above Nearest Drainage)	Donchyts/ Deltares, Google Earth Engine (GEE) Community [HAND, 2024]	30 m resolution
Soil data	FAO, 2024a and FAO, 2024b	Soil Texture and Soil Depth

B. Data Processing

1) **Land Cover**: The International Centre for Integrated Mountain and Development (ICIMOD) and the Forest Research and Training Centre (FRTC) collaborated to publish land cover data for 2021, which was utilised in this research [ICIMOD RDS, 2024]. From land cover, cropland data was extracted, which was 3.48 million hectares for the year 2021.
To validate this cropland data, a comparative study was performed where cropland estimated from ICIMOD and IMP 2019 were compared for the year 2018. As shown in Figure 4, similar statistical tendencies were observed. Thus, this increased the confidence in the ICIMOD datasets' applicability and utilisation.

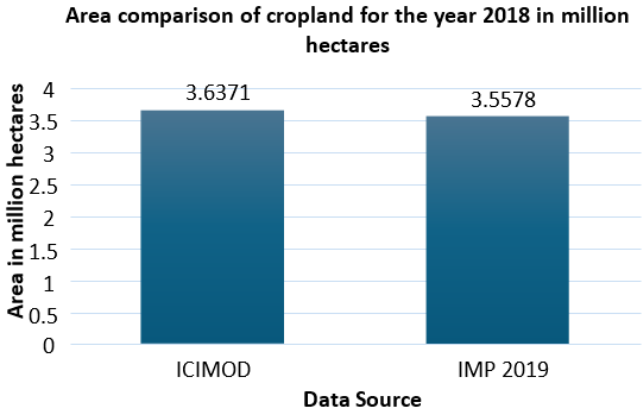

Figure 4. Comparison of the area of cropland between IMP 2019 and ICIMOD (in Million ha for the year 2018)

a) **Cropland**: The cropland of Nepal was extracted from land cover in 2021. The irrigated and non-irrigated land was separated from cropland.
   i) **Irrigated area**: The irrigated area was acquired from the Department of Water Resources and Irrigation, the Government of Nepal in the form of a polygonal shapefile [DoWRI, 2024].
   ii) **Non-irrigated area**: From cropland, non-irrigated areas were segregated after removing the irrigated area.

2) **Digital Elevation Model (DEM):** The digital Elevation Model with a resolution of 30m is utilized from the Google Earth engine provided by the NASA Shuttle Radar Topography Mission [SRTM, 2024].

   i) **Slope:** Slope was prepared using the DEM percentage. This prepared slope was reclassified into two categories with a slope having a threshold of 25%. This number was taken with the reference of integrated master plan [IMP, 2019] and all the slopes that were less than or equal to 25% were set as the input for further calculation.

3) **Soil**: Soil data is one of the most important factors that is necessary to be included in the process of any agricultural study. The plant is grown in the soil, but all types of soil may not be effective enough to be used for irrigation. Mainly soil texture and soil depth were taken as input for finding out the area of suitable land for irrigation. The vector data set is based on the FAO-UNESCO Soil Map of the World. The Digitised Soil Map of the World, at 1:5,000,000 scale.
   i) **Soil texture:** The soil texture was prepared with the datasets prepared by the Food and Agriculture Organisation (FAO). The classes that were selected as input were clay loam and loam [FAO, 2024a].
   ii) **Soil depth:** The vertical measurement from the ground surface to the underlying bedrock or any constraining layer that can prevent root growth is referred to as the "soil depth." It has a significant impact on how plants grow and develop because deeper soils often allow roots to have greater room to pierce and get water and nutrients. Soil depth is considered in land use planning and agricultural activities to maximize crop productivity and sustainable land management. The data that was collected for the input in the process as soil depth was from FAO [FAO, 2024b].

   From this, the soil depth having a value of more than or equal to 30cm was taken as suitable land for irrigation following the details of IMP 2019.

4) **River**: The source for the Dataset River was taken from the Hydro SHEDS global water datasets [Geoglows, 2024; Hydrosets, 2024]. These datasets provide only those rivers which have water availability for the year. Hydro RIVERS, a global river network depicted in vector form, comprises rivers that satisfy one of two criteria: they need to have a catchment area of at least 10 km^2 or an average flow of 0.1 m^3/sec. It is obtained from the gridded Hydro SHEDS core layers at a resolution of 15 arc-seconds, and it covers 8.5 million river reaches with an average length of 4.2 km, for a global total of 35.9 million km (about 22307225.8 mi). The primary characteristics of the dataset are limited geometric attributes, including river reach length, distance between headwaters and ocean outlet, river order, and an estimate of long-term average discharge. Every river reached in the Hydro BASINS database is linked to the corresponding sub-basin by means of a common ID.

The river is the main source of water, and it provides the water required for crops to be grown on specific agricultural land. Water availability is one of the major parts that need to be accumulated for lift irrigation.

This project uses a higher-grade water network to ensure water availability throughout the year. At the same time, the limitation of horizontal proximity of 3 km is applied following the standard of IMP 2019 and FAO.

5) **Height Above Nearest Drainage (HAND):** A topographic metric called height above nearest drainage (HAND) measures the vertical distance between a given place on the terrain and the closest drainage feature, such as a river, stream, or body of water. In hydrology and watershed studies, it is a crucial measure that aids in determining an area's drainage patterns and flood risk. HAND values are widely utilised in land-use planning and flood modelling to comprehend the possible effects of water flow on areas within a watershed. The global HAND dataset of 30 m resolution is freely available in the Google Earth Engine (GEE) Community [HAND, 2024]. For this specific project, the limitation of data was set to be 400m with several classes having an interval of 50m. Table 2 shows the class interval for HAND.

Table 2. Height above Nearest Drainage (HAND) interval

Class label	HAND interval (m)
Class 1	0-50
Class 2	50-100
Class 3	100-150
Class 4	150-200
Class 5	200-250
Class 6	250-300
Class 7	300-350
Class 8	350-400

6) **Physiographic region of Nepal:** Nepal is divided into five major physiographic regions, namely Terai, Siwalik, Middle Mountain, High Mountain and High Himalaya. Terai consists of plain areas with an elevation ranging from 60 to 200 masl. The Siwalik region, having the major portion of the Churia range, has elevation ranging from 200 – 1000 masl. The Middle Mountain consisting of a large area of the Mahabharata range covers the elevation ranging from 1000 – 2500 masl. Following that the High Mountain extends further towards the north with an elevation ranging from 2500 – 4000 masl. Other than that land having an elevation above 4000 masl falls under the High Himalayas region of Nepal.

C. Non-irrigated cropland suitable for irrigation

Following the steps outlined in the flow chart, the calculation of suitable non-irrigated cropland for irrigation was conducted using a raster calculator in GIS. This involved multiplying the non-irrigated area by factors such as slope (<=25%), soil texture (clay loam and loam), and soil depth (>=30 cm). The resulting

product represents the non-irrigated cropland that is suitable for irrigation. To validate this value, the same calculation was applied to cropland and suitable cropland for irrigation was computed. The computed suitable cropland for irrigation was compared with the Irrigation Master Plan (IMP) 2019 to observe the closeness in the output. This could suggest that the methodology employed was appropriate for identifying non-irrigated cropland suitable for irrigation purposes.

The second step was to assess the area of suitable land for lift irrigation. For this, the major inputs were nonirrigated cropland suitable for irrigation, river proximity of 3 km and height above the nearest drainage up to 400m.

D. Non-irrigated suitable cropland for lift irrigation

After preparing all these datasets, the final output was calculated using the product of river proximity, HAND, and non-irrigated suitable cropland for irrigation. The non-irrigated suitable cropland for lift irrigation was computed and compared to the statistics published in IMP 2029 to validate its output.

E. Crop water requirements

Crop water requirement, also known as ET crop, denotes the volume of water necessary to compensate for water loss through evapotranspiration. Essentially, it represents the water quantity essential for the optimal growth of various crops.

The crop water requirement is the amount equivalent to crop evapotranspiration. The crop evapotranspiration is the product of crop coefficient and reference evapotranspiration and is calculated with the help of daily maximum and minimum temperature, wind speed, daily sunshine hour and relative humidity from FAO Penman-

Monteith method as, $$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,\frac{900}{T+273}\,u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)}$$

Where,

ET0=reference evapotranspiration (mm/day)

Rn=net radiation at the crop surface (MJ m-2 day-1)

G=soil heat flux density (MJ m-2 day-1)

T=mean daily air temperature at 2 m height (^{0}C) U_2=wind speed at 2 m height (m s^{-1}) e_s=saturation vapour pressure (KPa) e_a=actual vapour pressure (KPa) e_s-e_a=saturation vapour pressure deficit (KPa)

Δ=slope vapour pressure curve (KPa $^0C^{-1}$) and γ=psychrometric constant (KPa $^0C^{-1}$)

The program includes a cropping pattern with the planting date, a set of typical crop coefficient data files, and crop coefficient data files (Kc values, stage days, root depth, and depletion fraction) along with the area planted (0–100% of the total area).

The computation of CWR and IWR is performed based on the following formula, as dictated by the model.

CWR = ETo* Kc

IWR = (ETo* Kc) – ER

The methodology that was adopted is shown in Figure 5.

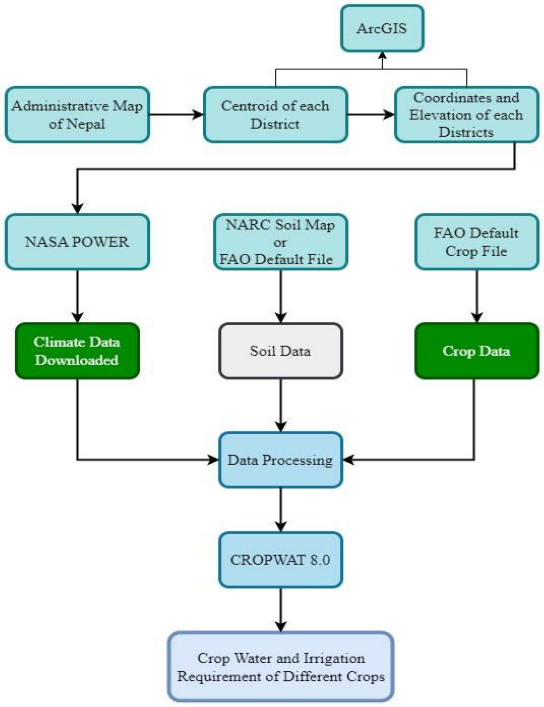

Figure 5. Methodological Framework for Crop Water Calculation

Based on the agro-ecological zone of Nepal, the mountain region that lies above the altitudes of 5,000 masl constitutes 12 districts, hills lie between altitudes of 600 and 5,000 masl constitute 44 districts, and the flat Terai region, a northern extension of the Gangetic plain, is located below 600masl elevation constitutes 21 districts. Initially, the crop water requirement for each district was estimated and thus the average crop water requirement for the country level was averaged.

In Nepal, a variety of crops are cultivated due to its diverse agro-climatic conditions. However, the most commonly grown crops include the cereal crops paddy, maize, and wheat, and the vegetables cauliflower and potato. Thus, these crops were taken as reference crops.

Thus, the average water requirement in (l/s/ha) for different crops is shown in Table 3.

Table 3. Average water requirements (in l/s/ha) for different crops

Region/Crop	Unit	Terai	Hills	Mountain	National
Paddy	l/s/ha	0.88	0.74	0.51	**0.71**
Maize		1.01	0.46	0.59	**0.68**
Wheat		0.60	0.40	0.42	**0.47**
Cauliflower		0.46	0.40	–	**0.43**
Potato		0.46	0.79	0.49	**0.58**

F. Power estimations

The power requirements for irrigation were calculated based on the following equation presented below:

Power (P) = **(Q * H * ρ * g) / η** determines the pump's power needs (kilowatts).

Here,

Q = Flow rate (Volume per unit time), H = head (lift height), ρ = density of water, g = acceleration due to gravity, η = pump efficiency

Based on expert consultations, an average head loss was estimated at 10% and an average pump efficiency of 50% is factored into these power requirement calculations.

G. Cost estimations

The cost estimates were derived using real project costs. Over 30 published bidding documents for lift irrigation systems from the year 2021 to 2023 were analysed [PPMO, 2024]. The average specific cost value per kW of pump capacity was derived from the bidding documents. The average specific cost was identified as NPR 2.3 million per kW. Similarly, for an off-grid system, an additional cost of NPR 100,000 per kWp is added referencing solar PV and the related balance of system cost.

Validation

To improve the platform and validate the input parameters and methodology, extensive bilateral discussions were held with relevant government organizations. The Ministry of Energy, Water Resources, and Irrigation

(MoEWRI), the Alternative Energy Promotion Center (AEPC), and the Department of Water Resources and Irrigation (DWRI) were among these organizations. Individual discussions with these government agencies have led to a thorough assessment and refinement of the methodology and input criteria based on their insightful recommendations.

Furthermore, a more comprehensive consultation was conducted to collect a range of viewpoints and feedback. 36 participants, representing 15 pertinent agencies took part in the validation workshop. Due to the wide involvement, the platform's criteria and procedures were carefully reviewed and verified during the validation workshop. During the validation workshop, experts from different agencies participated in a group discussion, followed by presentations from each group. They conducted a thorough examination of the criteria used in the input parameters as well as the methods used to estimate the potential area, power requirements, and cost. The professionals offered insightful recommendations that were properly documented. Additionally, their consensus was formally acknowledged and incorporated into the final methodology.

Results and Discussion

Based on the developed method, the initial data and hypothesis established, the results obtained, and their novel contributions are described in the following sub-sections.

Non-irrigated Cropland Suitable for Irrigation

From the calculations, the non-irrigated cropland suitable for irrigation was found to be 1.8 million hectares. To verify the accuracy of computed non-irrigated cropland suitable for irrigation, an equivalent calculation was made for cropland, which was estimated as 2.622 million hectares of cropland suitable for irrigation. Remarkably, a comparison study using information from the Irrigation Master Plan of 2019 [IMP 2019] showed that 2.54 million hectares of land were declared to be eligible cropland suitable for irrigation. The proximity of these values not only highlights the accuracy and dependability of the utilized computational method but also implies that the 1.8 million hectares of derived non-irrigated cropland suitable for irrigation are noteworthy.

This agreement between the calculated value and existing datasets validates the analytical process's robustness and confirms that the method is appropriate for estimating non-irrigated cropland that can be irrigated. The methodological framework produced by the methodical consideration of several geographical parameters and their subsequent harmonisation using GIS-based computations is in line with the larger cropland assessment landscape.

Non-irrigated Cropland Suitable Land for Lift Irrigation (potential area for lift irrigation)

After preparing all the datasets, the potential area for lift irrigation was calculated using the product of River proximity, HAND, and non-irrigated cropland suitable for irrigation. The potential area for lift irrigation is obtained as approximately 1 million hectares all over Nepal. Likewise, using the GIS technique, IMP 2019 also identified that about 1.1 million ha area is suitable for pumped irrigation which is similar to the PURE platform.

Power Demand

The PURE platform is capable of estimating the potential power demand for lift irrigation across the 3 levels of government administration and the five physiographic regions of Nepal. In this section, the results from the platform will be discussed. The input parameters were valued as per the stakeholder validation, using these inputs especially for the grid proximity and the reference crop following results.

National profile

At the national level, the platform estimates the potential power demand for lift irrigation from the level 3 river sources ranging between 800 and 1,304 MW for various reference crops. The estimated power demand for lift irrigation is 1,304 MW for the reference crop paddy, 1,261 MW for maize, 871 for wheat, 800 for cauliflower, and 1,071 MW for potato. Considering an aerial proximity of 2 km from the 11 kV line, the power requirement from the grid is estimated at 896 MW and 408 MW from off-grid for paddy. The estimated power demand varies with respect to the reference crops because of the water requirement. The detailed estimates for potential power demand for lift irrigation for various reference crops are presented in Table 4.

The power demand for lift irrigation varies significantly with the type of crop being irrigated. Paddy, being water-intensive, requires the highest energy. Maize and wheat follow with 1,261 MW and 871 MW respectively, indicating a lower water requirement compared to paddy. The calculated grid and off-grid demand further reveal the infrastructure dependency, with a substantial portion of the power demand

potentially being met by off-grid renewable sources. This breakdown aids in understanding the specific energy needs of different crops and highlights the critical role of energy planning in the context of crop diversity and seasonal variations.

Table 4. Estimated potential power demand for lift irrigation for various reference crops

Crop	Paddy	Maize	Wheat	Cauliflower	Potato
Estimated power (MW)	1,304	1,261	871	800	1,071
Grid (MW) *(grid proximity of 2 km)*	896	866	598	550	736
Off-grid (MW) *(grid proximity of 2 km)*	408	395	273	250	335

The detailed estimates of the potential area for lift irrigation and the estimated power demand using paddy as the reference crop for the seven provinces in Nepal are presented in Figure 6. In Koshi province, the total potential area for lift irrigation is estimated at 0.19 million hectares, which requires an estimated power demand of 293.89 MW. Considering the grid proximity of 2 km from the 11 kV line, the power required from the grid is 193.54 MW and from off-grid is 100.35 MW. Likewise, the estimated potential power demand for other provinces is 113.98 for Madhesh, 228.21 MW for Bagmati, 148.06 MW for Gandaki, 181.14 MW for Lumbini, 162.21 MW for Karnali, and 176.89 MW for Sudurpaschim.

The PURE platform provides estimates of potential power demand for lift irrigation at three levels of government administration. The following section delves into province-level insights, offering more localised information. Specifically, we will discuss the profile of Karnali province and Mahabu Gaupalika rural municipality of Karnali, detailing its power demand for lift irrigation and related data.

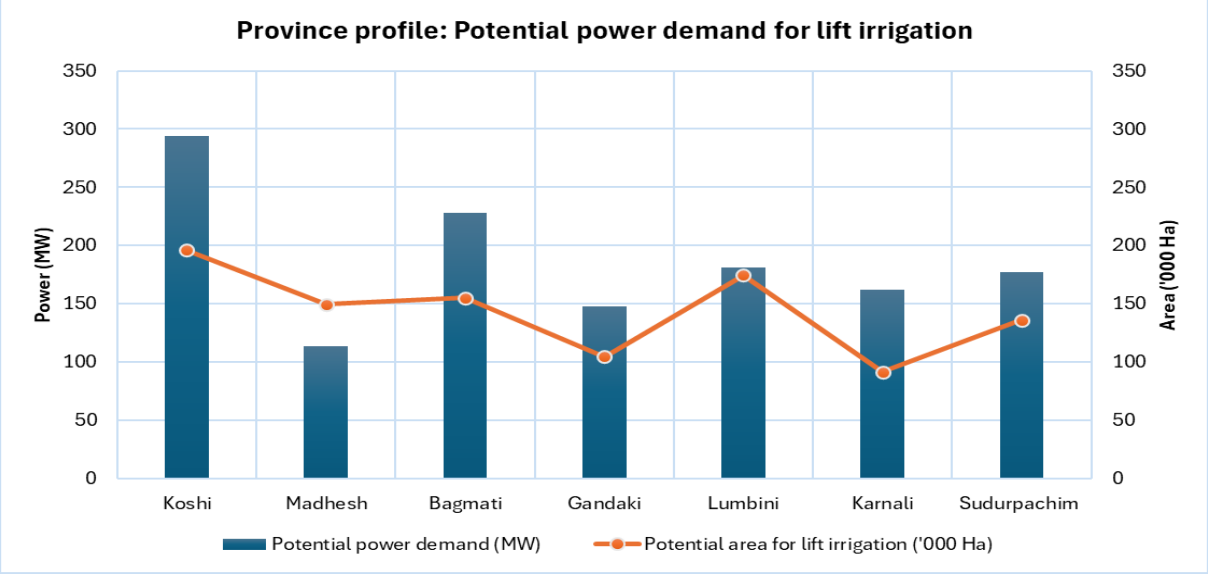

Figure 6. Potential power demand for lift irrigation for Nepal by province

Province profile: Karnali province

Additionally, similar estimates of power demand, potential area for lift irrigation, and the source of power requirement can be generated at the province level, providing more localised insights into the power demands for lift irrigation. Karnali is the largest province of Nepal with a total land area of 29,984 sq. km. The province has a total agricultural land area of 379,683 ha, with 45% of the land suitable for irrigation. Figure 7 shows the irrigation area profile of Karnali province. It indicates that the province has a 15,688 Ha irrigated area and a nonirrigated land area of 162,088Ha, of which 91,589 Ha area has potential for lift irrigation. It is estimated that the potential power demand required for the lift irrigation in Karnali is 162 MW. Considering the 2 km grid proximity, the power required from the grid is 58.22 MW and from the off-grid is 103.99 MW.

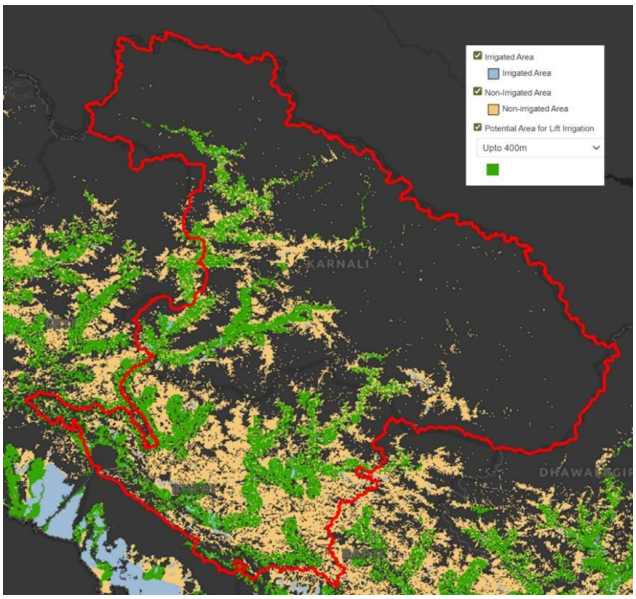

Figure 7. Karnali province irrigation area profile

Karnali Province's irrigation profile showcases the substantial potential for lift irrigation, especially in regions with significant elevation differences. The power requirement here underscores the necessity for a mix of grid and off-grid solutions to ensure comprehensive coverage. Given the province's vast area and varied topography, localised energy solutions, and integrating renewable sources, become pivotal for effective irrigation management.

The potential area for lift irrigation in Karnali is categorized based on different required lift elevations, ranging from 50m to 400m, at intervals of 50m from the river. At a 50m lift elevation, the potential area for lift irrigation is 46,784 hectares, which constitutes 51% of the total potential area for lift irrigation in Karnali. The power demand for this 50m lift elevation area is 35 MW. The cost of irrigation is relatively cheaper for lower lifts. Detailed potential areas for lift irrigation with respect to various lift elevations, along with the corresponding estimated power demand for Karnali, are presented in Figure 8-9.

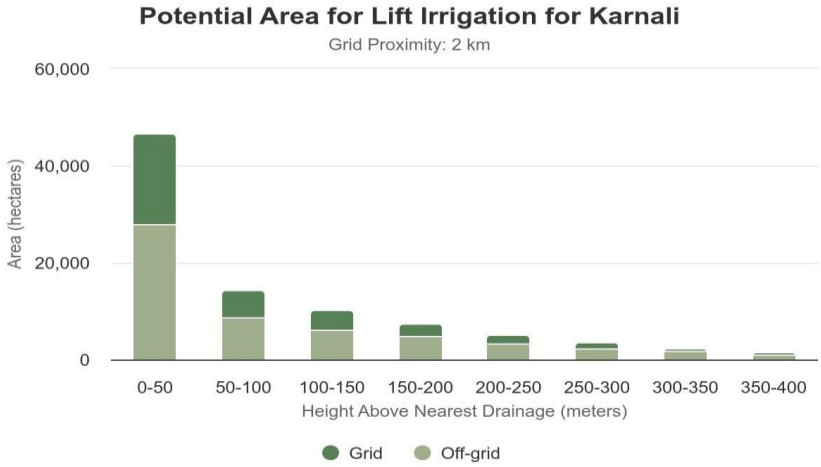

Figure 8. Potential area for lift irrigation with respect to lift elevation for Karnali

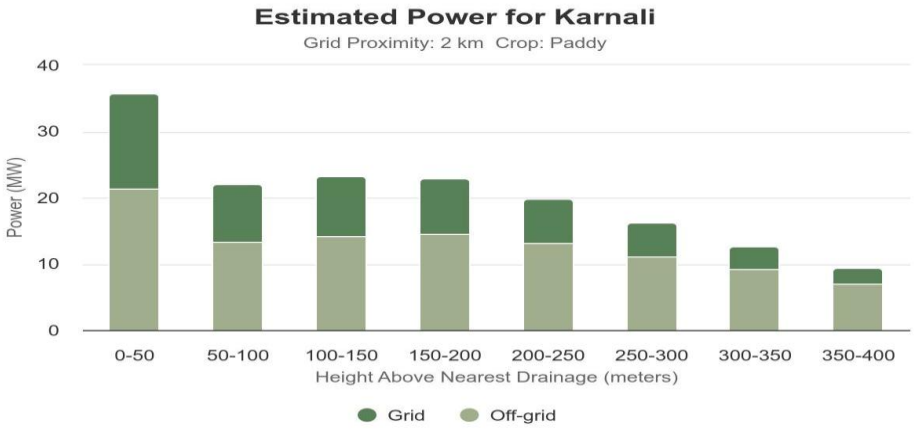

Figure 9. Estimated power demand for Karnali

Municipality profile: Mahabu Gaupalika

Similarly, the power demand and the potential area for lift irrigation can be analysed at the municipality and rural municipality levels. Additionally, similar estimations can be generated at the municipality and rural municipality levels, providing more localised insights into power demands for lift irrigation. This granularity helps in understanding the regional variations in energy needs and supports better planning and resource allocation.

There are 25 municipalities and 54 rural municipalities in the Karnali province. Mahabu Gaupalika is one of the rural municipalities in Karnali. It has a total agricultural land area of 3849 Ha, of which 2246 Ha is suitable for irrigation. It is estimated that a total of 1385 Ha potential area is available for lift irrigation in Mahabu Gaupalika. Figure 10 shows the available area for Mahabu Gaupalika. The power demand for lift irrigation for Mahabu Gaupalika is 2.75 MW, of which 1.4 MW from the grid and 1.35 MW from the off-grid.

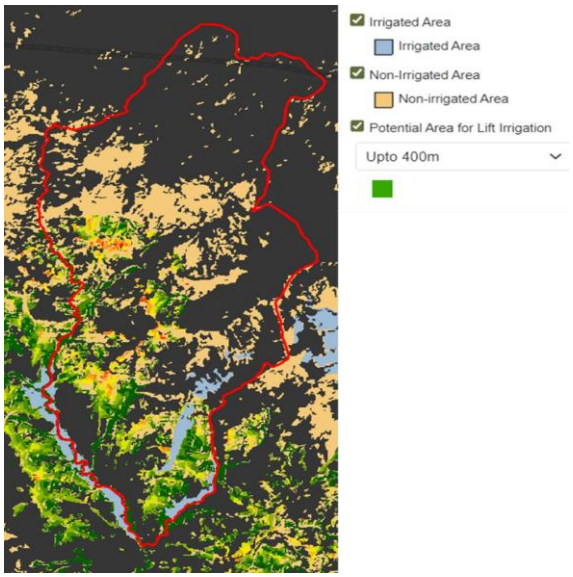

Figure 10. Local profile: Area profile for Mahabu Gaupalika

Detailed analysis at the municipality level, such as Mahabu Gaupalika, provides a micro-level understanding of irrigation needs and power demands. This level of detail is crucial for effective resource allocation and planning, ensuring that even remote or smaller regions receive appropriate attention for their irrigation and power needs.

Further, the platform reveals that the 491 Ha can be irrigated with a 50m lift elevation and 285.21 Ha with a 100m lift elevation. Detailed potential areas for lift irrigation with respect to the lift elevation and the estimated power demand with respect to lift elevation for Mahabu Gaupalika are presented in Figure 11-12. Similar results can be drawn for all 753 municipalities and rural municipalities in Nepal, this creates a better understanding of the need, power- demand and techno-economic feasible lift areas which can be used as decision support for planning and resource mobilisation.

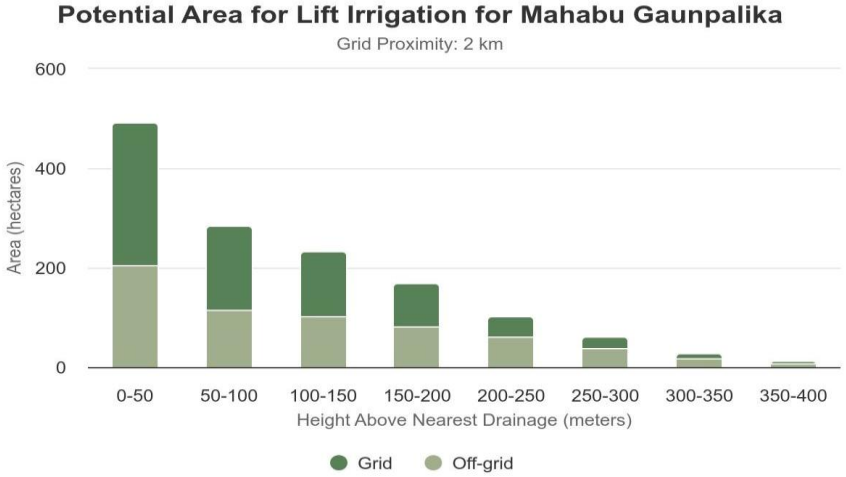

Figure 11. Potential area for lift irrigation with respect to lift elevation for Mahabu Gaupalika

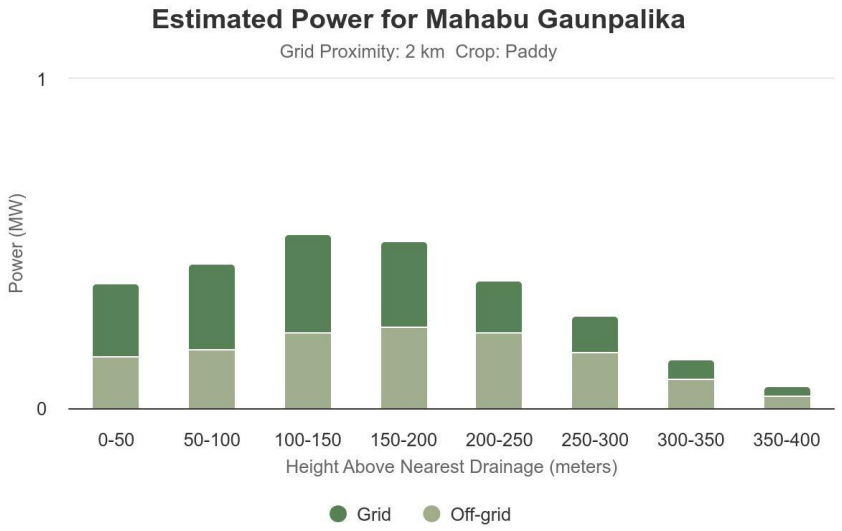

Figure 12. Estimated power demand for Mahabu Gaupalika

Physiographic perspective

From a physiographic perspective, the middle mountains of Nepal show significant potential for lift irrigation. The analysis identifies suitable areas and emphasises the critical role of renewable energy in this region. The platform identifies 767,961 Ha of cropland in the middle mountain region that is suitable for irrigation. However, only 6.5% of this land has been irrigated to date, leaving 718,038 Ha of non-irrigated land available. Out of this non-irrigated land, approximately 51%, or 367,955 Ha, is suitable for lift irrigation. Detailed physiographic profiles of potential power demand for lift irrigation and areas suitable for lift irrigation for Nepal are presented in Figure 13.

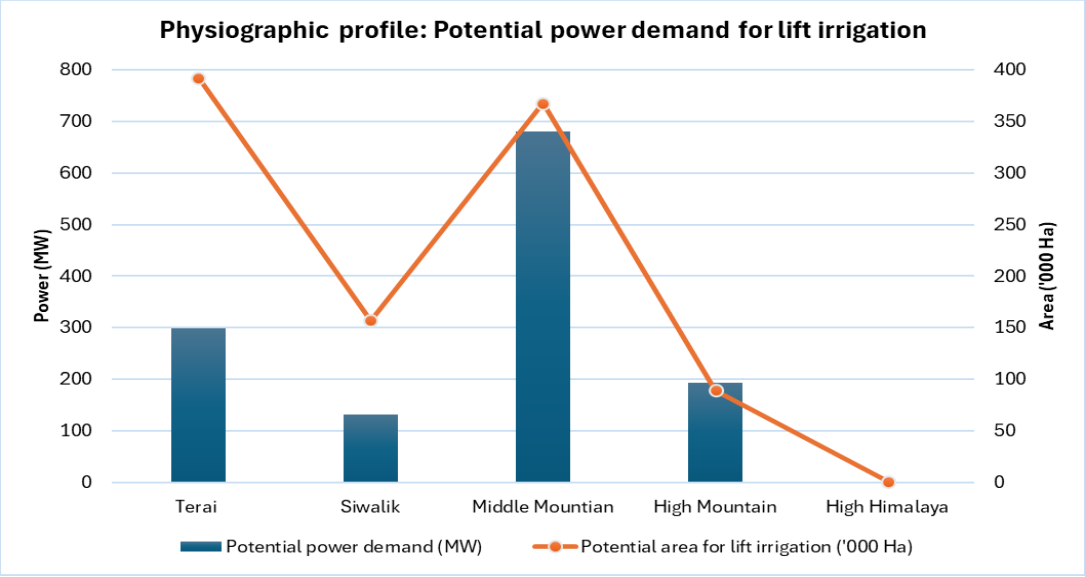

Figure 13. Physiographic profile: Potential power demand for lift irrigation

The platform estimates the highest potential power demand for lift irrigation in the middle mountain region to be 694.64 MW, with 444.39 MW required from the grid and 235.25 MW from off-grid sources. This significant off-grid power requirement indicates a reliance on renewable energy solutions, particularly in the middle mountains, where traditional grid access might be challenging. These findings underscore the importance of both grid and off-grid solutions to meet the varying power demands for different crops and regions in the hills and mountains of Nepal. Adopting renewable energy for lift irrigation not only addresses the immediate irrigation needs but also promotes sustainable agricultural practices in these challenging terrains. These estimates provide crucial data for policymakers and stakeholders to develop strategies for energy planning and resource mobilisation in agricultural sectors. Figure 14 shows the lift irrigation opportunity in the middle mountain.

Figure 14. Estimated power demand for the middle mountain

Conclusion

The PURE platform's ability to estimate the potential renewable power demand for lift irrigation in Nepal has provided several key insights and contributions:

1. **Spatial and Field Information for Decision Support:** By utilising spatial and field data, the platform provides robust decision support for resource and strategic planning. This information aids in identifying suitable irrigation areas and understanding the specific power demands, facilitating better planning and resource allocation. The integration of GIS-based analyses ensures that the economical assessments.
2. **New Knowledge on Lift Irrigation RE Potential:** This study offers a comprehensive estimate of the renewable energy demand for lift irrigation, addressing various crops and regions across Nepal. The platform identifies potential areas for lift irrigation and quantifies the power requirements, contributing new knowledge to the field. This is particularly significant as it provides a clear picture of the energy landscape necessary to support lift irrigation systems across different topographies.
3. **High Demand for RE in Hills and Mountains:** The study highlights the significant need for renewable energy to irrigate the hills and mountains of Nepal. Given the challenges of grid access in these regions, off-grid renewable energy sources will play an essential role in providing reliable irrigation solutions.

4. **Detailed Energy Demand Analysis:** The PURE platform's ability to provide power demand for different crops and regions at various administrative levels (national, provincial, district, and municipal) and physiographic regions of Nepal allows for tailored energy strategies for irrigation planning. This granularity supports targeted interventions and resource distribution, ensuring that specific local needs are met effectively.
5. **Elevation-Specific Insights:** The analysis provides detailed elevation-specific estimates for lift irrigation, which are crucial for assessing the feasibility, power, and cost requirements of irrigation projects at different elevations required for lifting water. This comprehensive breakdown allows for the prioritisation of economically viable lift irrigation systems. As elevation increases, both the cost and power requirements rise, underscoring the necessity of identifying technically and economically feasible sites. This approach enables decision-makers and planners to make informed decisions on optimising resource mobilisation, ensuring a balance between feasibility and cost-effectiveness**.** These insights are instrumental in guiding strategic planning and implementation of sustainable irrigation solutions, fostering improved agricultural productivity and resilience in diverse topographical conditions.
6. **Resource Mobilisation and Planning:** The comprehensive data and insights provided by the platform can be used as informed decision support for planning and resource mobilisation. This facilitates a coordinated approach to developing irrigation infrastructure and renewable energy deployment, ensuring that investments are directed to the most impactful areas.
7. **Future Research and Optimisation:** The findings lay the groundwork for future research aimed at refining energy demand estimates and exploring further integration of renewable energy sources. This continuous improvement cycle will help optimise lift irrigation systems, making them more efficient and sustainable over time.

Acknowledgement

The PURE 2 platform was part of the ICIMOD's Energy Intervention's Green Energy Management for Mountain Economies in Nepal (GEM-Nepal) project, funded by the Royal Norwegian Embassy in Kathmandu, Nepal. We thank Mr Mewang Gyeltshen, Mr Manoj Panta, and Mr Tikaram Adhikari for their support during the course of the study. We thank the Alternative Energy Promotion Center (AEPC), the Government of Nepal, the Ministry of Energy, Water Resources and Irrigation (MoEWRI) for Nepal, the Department of Water Resources and Irrigation (DWRI), and the Department of Agriculture (DoA).

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4b. Affordable and Clean Energy

Abstracts

Submission ID: 49

Encouraging Biogas Plant Construction in Nepal: Should Carbon Revenues Be Spent as Interest Rate Subsidies, Environmental Income Payments or Purchase Subsidies?

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Abstract

Governments and project developers in developing countries can obtain substantial income from carbon revenues as households make the transition to clean energy technologies and reduce their greenhouse gas emissions. These revenues can be used in various ways to encourage further investments in clean energy. This paper examines the effectiveness of three alternative policy instruments for supporting this clean energy transition in relation to cooking with biogas plants in Nepal – 1) carbon revenues as purchase subsidies on biogas plants, 2) distribution of environmental income to households for continuing use of biogas plants, or 3) interest rate subsidies related to purchases of biogas plants on credit. Thus far the sectoral focus has been on purchase subsidies, but these are increasingly declining in their effectiveness. Our results identify the effectiveness relative to government cost from these three types of potential government policy. We find that compared with purchase subsidies, credit subsidies on shorter-term loans, preferably 3 years or less, have the lowest government cost to achieve a given increase in purchases of biogas plants. Moreover, combining credit subsidies with distributing modest amounts as environmental income to biogas purchasers, can further increase the rate of uptake of biogas plants. These results support the policy recommendations to (1) mainstream larger interest rate subsidies for biogas credit and (2) channel some carbon revenues to those who generate carbon credits. These findings have relevance for both the Nepali and international organisations concerned with improving energy access, generating carbon credits, improving environmental and health outcomes, and improving community welfare.

Submission ID: 67

Identifying Clusters for Municipal Solid Waste Management Facilities and Investigating Different Quantity-Based Approaches for Waste-To-Energy Generation in Nepal

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Abstract

Nepal has three administrative divisions, and local levels are responsible for managing municipal solid waste (MSW). Due to the lack of proper facilities, most municipalities are collecting, dumping, and burning solid waste, which is hazardous. There are few waste-based industries in Nepal, but due to insufficient raw materials, most are starving and have faced sustainability challenges. Clustering could create a better environment by increasing the availability of waste quantity not only for waste-based industries but also to add hands in the process of proper waste management. No literature on clustering techniques in the country has been found, and the study has filled the gap. The study has identified a suitable location for MSW management facilities using QGIS for waste collection and management all over Nepal, focusing on metropolitan and sub-metropolitan areas. Further, the study has quantified the waste generation potential based on the population and the availability in clusters based on 10, 25, and 50 km diameter coverage area. In addition, based on the quantity of waste generation and available literature, various possible valorization approaches for waste-to-energy were discussed. The study has identified ten different clusters covering six metropolitan and 11 sub-metropolitan cities and surrounding municipalities. Out of the total 6,963 tonnes/day, metropolitan and sub-metropolitan cities account for about one-fourth of the waste. Based on the quantity of waste available, the study has identified three different approaches for waste valorization: fractionation for syngas and methane production, gasification for electricity and heat production, and gasification for hydrogen and liquid fuel production. The study's findings could help policymakers promote clustering techniques, and entrepreneurs establish waste-based industries.

Submission ID: 68

Environmental Evaluation of Innovative Thermochemical Energy Storage Materials: A Preliminary Life Cycle Assessment

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Abstract

In the ongoing transition toward sustainable energy systems, thermal energy storage stands out as a pivotal technology, providing the capability to store and release heat or cold based on inherent physical and chemical properties. Within the context of the EU-funded 'Innovation Ecosystem - Sicilian MicronanoTech Research and Innovation Center' (SAMOTHRACE) project, a dedicated team of researchers is committed to advancing sustainable energy storage technologies.

One of the tasks of the project involves the development of innovative materials for thermochemical energy storage. Envisioned to be low-cost, non-toxic, and non-flammable, these materials should also represent an environmentally friendly alternative. Considering that most studies on these innovative materials generally focus only on their thermodynamic properties and costs, the primary objective of this study is to assess their potential environmental impacts, with a specific focus on the investigated organic thermochemical compounds, including di-sodium succinate and lactate salts. These compounds are explored as substitutes for traditional inorganic counterparts like halide hydrates, nitrate hydrates, sulfate di-hydrates, etc.

Adopting a Life Cycle Assessment (LCA) approach, the study evaluates the potential environmental impacts of these materials across their entire life cycle, encompassing production, use, dismantling, and disposal phases. This preliminary investigation focuses solely on material properties, excluding considerations about other components typically included in thermal storage systems and infrastructure.

Thermochemical properties, including specific storage capacity per kg of material, evaporation enthalpy of water at the adsorption temperature, integrated adsorption potential, and sensible heat capacity, are investigated for comparison purposes. Inventory data sources include both primary and secondary data. In particular, literature reviews and responses from a questionnaire sent to the project-involved laboratories are collected. Background processes are estimated using the Ecoinvent 3.8 database, supplemented by a stoichiometric approach for candidate materials lacking data.

The findings provide valuable insights into the environmental impacts of these innovative materials, identifying hot spots and potential trade-offs. This preliminary life cycle analysis provides critical information to guide the development of sustainable energy storage solutions. Furthermore, the findings will support future LCA studies by offering critical discussions on data uncertainty and limits, thereby enhancing the robustness of environmental assessments in the realm of thermochemical energy storage.

This research aims to contribute to the achievement of SDGs 7 and 12 by evaluating the potential environmental impacts of alternative chemical materials that can be used in thermal energy storage. The new technological design not only increases the share of renewable energy in the global energy mix allowing a long-term storage of renewable or wasted thermal energy. In addition, it offers an environmentally sound management of chemicals and waste, substantially minimizing their adverse impacts on human health and the environment through the use of organic compounds.

This work has been funded by European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022). However, the views and opinions expressed are those of the authors only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Submission ID: 87

The Use of Smart Apps to Promote Energy-Saving: Householders' Response and Behavioural Change in Hong Kong (A Case Study of Sai Kung & Sheung Shui Community)

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Abstract

To foster the smart energy transition, the Hong Kong government has published the Climate Action Plan (2017) and Smart City Blueprint (2020), alongside the introduction of the Carbon Neutrality Goal by 2050 (ENB, 2017; HKSAR, 2020). Two monopolised power companies have implemented the smart meter rollout plan from 2020 to 2025 (CLP, 2018; HEC, 2020). The Department of Geography (GEOG) of Hong Kong Baptist University (HKBU) has started the smart low-carbon transition project, which aims to motivate energy behavioural change via bottom-up approaches. The interdisciplinary researcher teams formed by academic expertise in geography, physics, computer sciences and visual arts have developed the Smart Energy Envisioning (SEE) apps. The smart apps can provide Real-Time data visualisation, Energy-Saving Coins and Rewards, and AI-conversational chatbot for householders. It also acts as a communicative agent to generate, collect and interpret large-scale datasets. We aim to achieve an annual average of 10% electricity consumption reduction, as well as knowledge, attitude and behavioural change after 3-month app-based intervention (HKBU, 2021).

The research would address the following question: (i) How do householders' response and interact (e.g. using percentage, using frequency, which and when) with 6 app-based energy behavioural change interventions? (ii) What are the impacts (e.g. total electricity consumption change, energy behavioural change, knowledge and attitude change) of 6 app-based energy behavioural change interventions? (iii) What are the factors (e.g. socio-demographic features, dwelling characteristics, type of electricity consumers, and other factors) explaining the differences on app-based interaction and energy behavioural change? This study is a case study of Hong Kong with Two Comparative Communities. Hong Kong is a significant case for studying the role of households in smart energy transitions due to the dense urban environment and smart city transformation (HKSAR, 2020). Sai Kung and Sheung Shui are two significant communities due to its climate resilience capability, diversity of housing types and strong community bonding. During the 3-month app-based interventions (Sai Kung: 09 Aug-08 Nov 2023; Sheung Shui: 18 Aug - 17 Nov 2023), 120 households were selected to interact with 6 app-based energy behavioural change interventions. 80 households and 40 households were served as intervention and control group respectively.

Interdisciplinary multi-methods with 2 main types of data, including (i) quantitative and (ii) qualitative data collection. The former one includes Questionnaire T1&T2, collection of electricity bills and real-time electricity consumption. The later one comprises focus group sharing and in-depth household interviews. This study is novel in several aspects. Firstly, we develop a holistic app-based energy behavioural change interventions for a smart low-carbon community. We develop 6 app-based interventions, such as real-time data visualisation, financial rewards and AI-conversational chatbot, derived from 6 motivational factors of energy-saving behavioural changes. Secondly, we interpret the progression of energy-saving behavioural change via comprehensive indicators (e.g., total electricity consumption change, energy behavioural change, knowledge and attitude change). Therefore, the research outcomes would result in a positive impact on a wide range of stakeholders, as well as provide useful policy implications for smart city transformation and decarbonisation measures.

Submission ID: 304

Waste to Energy - Refuse Derived Fuel Briquettes (RDF) from MSW as Fuel for Small Scale Industries and Partial Solution to Waste Management

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Abstract

Energy recovery from municipal solid waste (MSW) has been gaining attention as one of the world's alternative and environmentally friendly methods for waste management. MSW management is one of the major issues in developing nation like Nepal, causing environmental pollution from poor management and open burning. Open burning of waste in the mountainous areas even cause even more pollution. On the other hand, traditional sources of energy such as fuelwood, coal, etc. are getting expensive and also cause pollution from their use in industrial kilns and furnaces. This research work is based on the research work conducted by Centre for Energy and Environment Nepal (CEEN) to explore the possibilities of producing refuse derived fuel (RDF) briquettes using some combustible portions of the (MSW), namely plastic waste/wrappers, paper, rubber, cloth, etc. and testing them as alternative fuel to traditional fuelwood being used in the clay craft kilns for baking clay pots in Thimi and Thermax boiler in Pashmina factory in Bhaktapur District.

The combustible waste (paper, plastic, rubber, clothe and biomass) was collected and processed (sorting, drying, shredding) for production of refused derived fuel (RDF) using screw extruder technology. First RDF-1 was produced using 50:50 paper and noddle wrappers, then RDF-2 was produced using 57.25 % plastics, 21.54% cloth, 13.57 paper, 7.60% rubber. The fuel characteristics (proximate analysis, calorific value) of RDF briquettes were determined and then tested in clay craft pottery kilns and boiler in Bhaktapur. The emissions from the combustion of the wood fuel and RDF in the kilns were monitored during firing of the kilns.

Refuse derived fuel briquettes were found to be more efficient than fuelwood, both in terms of resource consumption and emission control. Where 80kgs of wood was required for firing, 31 kgs of RDF-1 could complete the firing process of 7 hours in baking clay pots. In case of using as boiler fuel for steam generation for treatment of pashmina yarns and fabrics for a time period of 5-6 hours, 95kgs of RDF-2 was used instead of 200kgs of wood fuel. Flue gas emission (CO, CO_2, SO_2) can be minimized by using limestone or slaked lime during RDF production.

About 20 kg of RDF briquettes were sent to conduct some simple tests as space heating fuel in the Solokhumbu area. The observations received suggested them as better fuel in comparison to yak dung.

4c. Climate, Tourism and Sustainable Development

Submission ID: 109

How Sustainable Tourism Empowers Community and Conservation: Perspectives from Rural India

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Abstract

Over the past 20 years, agrotourism as a part of ecotourism has been on the rise, and people have been gladly accepting it to get away from the hustle and bustle of city life (Xu *et al.*, 2023). To foster rural community and optimize local natural resources, agrotourism acts as a powerful tool. Case studies present that agrotourism and sustainable tourism are inherently intertwined because of the philosophical similarities between both concepts. UN (2017) rightly addressed that (SDGs target 8.9): *"by 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products".* Presently, agrotourism has gained support from many regional and local governments as a means of bringing new finances into rural regions, promoting economic growth, and creating empl0yments. It further helps to identify problems caused by lost economic opportunities and population decline which associated with agricultural collapse. It is important to acknowledge the significance of science related to tourism climatology, as it helps practitioners and policy makers to navigate and unpack unique experiences of any tourist destinations while fostering environmental stewardship. However, it is also crucial to address the multitude of challenges faced by the practitioners and policymakers from implementing the principles of sustainable tourism to leveraging economic realities and ensuring community wellbeing. This research paper tries to explore: i) how can agrotourism contribute to the development, diversification, and opportunities of rural economies; ii) how to develop a flexible and adaptable framework to implement sustainable agrotourism initiatives by considering diverse local contexts and requirements. To get a holistic understanding of agrotourism at local level, this research has selected a village Anegundi, located Deccan plateau of South India – surrounded by river in one side and hills in other three sides. Due to its unique geographical location, it presents huge potential for agrotourism as it has innumerable farmlands, skilled farmers, and rich cultural heritage of Vijayanagara Empire (17th Century). Primary research evolves through observations and semi-structured interviews with the experts, several stakeholders, and the farmers. Data analyses reveal there needs a climate responsive plan as tourism climatology plays a crucial role in identifying tourists' season, promoting sustainable practices, attracting eco-conscious tourists, and above all fostering biodiversity. By factoring in tourism climatology insights, this paper proposes a framework which would guide to i) bridge the gap by connecting tourists and information of the agrotourism destination; ii) unearth opportunities through jobs, skills, and community benefits; and iii) promote sustainable practices within the community. This framework would contribute towards responsible practices and optimize visitor experiences aligned with the climatic realities. Based on the inferences it further proposes an agrotourism-based design intervention (viz. a website and a brief spatial plan of the destination) which provides an in-depth itinerary for stakeholders to unpack the importance of social and environmental significance of the tourist destination. The framework and the design intervention would be useful for researchers, practitioners, and policy implementors from the pertinent field of interests who wants to become a game changer within the sustainable tourism ecosystem.

Submission ID: 167

Empowering Communities and Promoting Sustainable Development through Tourism: The Case of Hornbill Festival of Nagaland in India

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Abstract

Sustainable development through tourism plays a pivotal role in empowering communities and achieving their aspirations for well-being, encompassing economic, social, and environmental sustainability. In the same context, UN Sustainable Development Goals (SDGs) 11.4 and 13.2, address the significance of cultural and natural heritage preservation as well as impact of climate change on local ecosystems. Existing research reveals because of the vulnerability of mountainous destinations, collaborative efforts are crucial for responsible and comprehensive development of the community. Although researchers have rightly pointed out that sustainable tourism is the key concern for community's development, however, responsible tourism gets inadequate attention in the present context. Against this background this research tries to explore a) how to promote sustainable development through tourism within an indigenous community and b) what are the potential threats for practising the same. To attain these objectives present research particularly selects the Hornbill Festival of Nagaland due to its uniqueness of cultural and natural heritage. Nestled in India's Northeastern part, Nagaland is known for its adventurous mountainous terrain and typical harsh climate. The Hornbill Festival started in 2000 to celebrate indigenous people's rich traditional culture through vibrant costumes, rhythmic beats, and musical narratives. Data for this research were gathered from fieldwork conducted between 2013 and 2019, through observations and in-depth interviews with domain experts, different stakeholders. Investigation shows the Hornbill Festival has experienced substantial growth, attracting increasing numbers of tourists and driving economic, political, social, and infrastructural changes within the indigenous community, viz. Naga community. International and domestic tourists have played a significant role in this transformation towards holistic well-being and fostering cultural exposure. Despite positive outcomes, the research identifies internal and external challenges, including political conflicts, environmental hazards due to overcrowded tourists, unplanned infrastructures, and socioeconomic imperatives – which are threatening towards sustainability at present. Hence, the research underscores the importance of responsible tourism initiatives in fostering indigenous community empowerment and sustainable development. It further proposes a flexible framework for stakeholders to evaluate existing policies and addresses sustainability risks and emphasizes the need for ongoing collaboration and adaptation among different stakeholders. By embracing responsible tourism practices and leveraging flexible and collaborative frameworks, stakeholders would able to navigate challenges, reflect on the mistakes and eventually would able to promote holistic development for the community. This paper serves as a resource for community leaders, tourism entrepreneurs, policymakers, and researchers, offering insights into the complexities of sustainable tourism development and strategies for long-term success.

Keywords: *Sustainable Development, Responsible Tourism, Hornbill Festival, Nagaland, Indigenous Community, Empowerment*

Submission ID: 179

Navigating the Climate-Tourism-Sustainability Nexus from Crisis to Opportunity: A Case Study of Shimla

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Abstract

The intersection of climate, tourism, and sustainability has garnered significant attention in recent years, particularly in regions heavily reliant on tourism for economic sustenance. This paper divulges into the intricate dynamics between the economy, climatic calamity and sustainable development goals eleven and thirteen that are sustainable cities and communities and climatic action respectively in context to a hilly region, Shimla, nestled in the Himalayas. The aim is to focus on understanding the urgency to deal with climate change and to identify challenges faced by Shimla's tourism and agriculture dependent local communities to ascertain the shortcomings in the current existing policies to provide solutions to combat effects on the main revenue-generating avenues like agriculture and tourism for Shimla region. Empirical analysis and theoretical inquiry are employed through on-site visits, surveys, experiments, interviews, focus groups, participant observations, and statistical analysis to collect and analyze primary and secondary sources data to distinguish and resolve the multi-faceted environmental factors emerging as a threat to sustainable development of communities and to document analysis to gather rich, detailed insights into the phenomena under study. The paper views sustainability from different perspectives by laying emphasis on some aspects like sustainable infrastructure, tourism planning, tourism management and ecotourism by examining how present and future climate scenarios impact weather patterns, climate change, and tourism and agriculture sustainability particularly in regions like Shimla, where livelihoods are intricately intertwined with environmental conditions. Ultimately, this paper underscores the imperative of addressing loss of life and property incurred by locals due to recent landslides impacting the entire connectivity and livelihood matrix. This study examines international cases with comparable geographical and climate conditions, aiming to propose enhancements in policies and strategies for adaptation. The insights gained from this research endeavour are anticipated to address the challenges posed by climate change, fostering the development of human settlements that are secure, adaptable, and environmentally sustainable. Furthermore, the outcomes of this investigation aspire to contribute towards the realization of a global vision wherein all individuals have access to affordable, dependable, and sustainable energy sources. The overall study will help overcome the existing challenges by identifying limitations of current policies and will contribute to a broader discussion on the future direction of policy and urban planning in tourism and agriculture-focused regions such as Shimla.

Submission ID: 201

The Impact of Policy and Entrepreneurship in Promoting Sustainable Tourism: The Case of Yuwan Village in Shaanxi Province of China

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Abstract

The sustainable development of tourism needs contribution from stakeholders including government agencies, private sectors, various institutions and local communities, etc. This paper is to show how policy and entrepreneurship play critical roles in promoting sustainable tourism.

Field study is used to analyze the case of Yuwan Village ecotourism. Located in southern Shaanxi Province, Yuwan Village is a rural area in the lower mountains Qingling Mountains, with a good natural endowment, but poor development conditions. Ecotourism has been developed jointly to realize. We visited the village, reviewed the various stakeholders, including farmers in the village, local communities, banks, government agency clerk, mangers of the involved company.

Based on our field review towards them, we have identified that there are some general problems in promoting ecotourism. First of all, developers are lack of comprehensive ecotourism thinking. The reasons may be neglecting the critical role of ecological factors, and short of institutional support which hinders the execution of even formerly-designed ecotourism. Secondly, the ecotourism needs financial support, which is often in a shortage. For ecotourism specific investment targeting ecological goals generates an overall higher capital demand. Thirdly, ecotourism require infrastructure more nature-based, which arouse problems of understanding local nature conditions and making good used of them.

In terms of Yuwan Village ecotourism case, the joint effort has turned out contributing the success of its business model. The leading private sector designed the ecotourism-based strategy, which is “restoring rice paddies to attract *Nipponia nippon* before developing accommodation in the village”. Government policies have been made good use of developing the ecotourism, such as Western Development, East-West Collaboration, Rural revitalization. Nature-based infrastructure has been designed and constructed, such as abandoned hydropower stations renovated into Yuwan Village Complex, camps constructed above the rice fields.

This paper focus on the business model of Yuwan ecotourism benefiting the various stakeholders, aims to demonstrate that strategies of sustainability and sustainable innovations depend on both private and public supports and initiatives. On the public side, the government policy in China has offered fundamental policy framework. On the private side, the case study of Yuwan Village shows that individual contribution of an entrepreneur has been key to initiate ecological and social innovation in this rural area.

This research is especially related to SDG+Target: 8.9 (to promote sustainable tourism that create jobs and promotes local culture and products); 10.4 (Adopting policies and progressively achieve greater equality); and 15.1 (to ensure the conservation, restoration and sustainable use of terrestrial ecosystems, in particular mountains.) This paper focus on a case developing ecotourism in mountain area in central China, which will contribute to the general topic of the conference linking the future of mountain and ocean.

Full Papers

Submission ID: 123

Managing Tourism Sustainably: Overtourism in the Ozark Mountains, USA

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Abstract

This study examines the impacts of tourism in four destinations in the Ozarks: Branson, Missouri, Lake Ozark, Missouri, Eureka Springs. Arkansas, and Mountain Home, Arkansas, particularly from the lens of overtourism. It utilizes maps, literature, and stakeholder interviews to evaluate the current state and future risks of overtourism in the Ozarks and examines best practices to mitigate identified problems. Overtourism is defined by the United Nations World Tourism Organization as "the impact of tourism on a destination, or parts thereof, that excessively influences perceived quality of life of citizens and/or quality of visitor experiences in a negative way," and can impact tourist-oriented communities in a variety of ways. Some common issues that can be caused by overtourism are decreased quality of life for community residents, increased housing costs or shortages of long-term housing, transportation infrastructure deficits, ecological destruction, and pollution, which can all contribute to the destabilization of critical infrastructure such as in education or emergency services, as full-time residents begin to move away. This study analyzes impacts of overtourism in the Ozarks and determines general guidelines for mitigation strategies to avoid further or future impairment and degradation.

Introduction

Tourism is one of the fastest growing economic sectors across the globe. This industry grew from approximately 25 million worldwide arrivals in 1950 to about 1.3 billion as of 2022 (Figure 1) (Statista.com, 2024). Growth has steadily been increasing and continual with the exception of the Covid19 outbreak. Although increased tourism can provide many benefits to destination communities, insufficiently managed tourism can lead to a phenomenon known as overtourism. Overtourism is defined by the United Nations World Tourism Organization (UNWTO) as, “the impact of tourism on a destination, or parts thereof, that excessively influences perceived quality of life of citizens and/or quality of visitors experiences in a negative way (UNWTO, n.d.).” In a similar fashion, and tailored to the concept of sustainability utilized within this paper, the Center for Responsible Travel (CREST), defines overtourism as “tourism that has moved beyond the limits of acceptable change in a destination due to quantity of visitors, resulting in degradation of the environment and infrastructure, diminished travel experience, wear and tear on built heritage, and/or negative impacts on residents” (CREST, 2018). When studied from the lens of the four cornerstones of sustainability (society, economy, environment, culture), this can mean that residents of destination communities suffer decreased quality of life (social cornerstone), a degraded physical environment from over-use of resources, economic instability economy from tourism seasonality, and cultural erosion from outside influences, such as chain businesses, or mass marketing. As tourism success within a community works across the networks of the cornerstones, for the tourism industry to flourish sustainably, it must address all cornerstones.

Study Area

Overtourism is a relatively new area of study, but its significance cannot be understated considering the rapid growth of the tourism industry. While many popular destinations have been examined, this research aims to understand the ways in which overtourism has influenced communities in the Ozark Mountains region in the United States of America (USA). The area is also referred to as the Ozark Highlands, or simply the 'Ozarks', as will be used for the purposes of this study. The Ozarks region lies in the southcentral portion of the United States and is situated in central to southern Missouri, Northern Arkansas, a small part of eastern Oklahoma, and an even smaller part of the southeast corner of Kansas (Figure 2). The terrain varies in topography, but much of the area is covered in rolling hills or plateaus dotted with lakes, streams, and rivers.

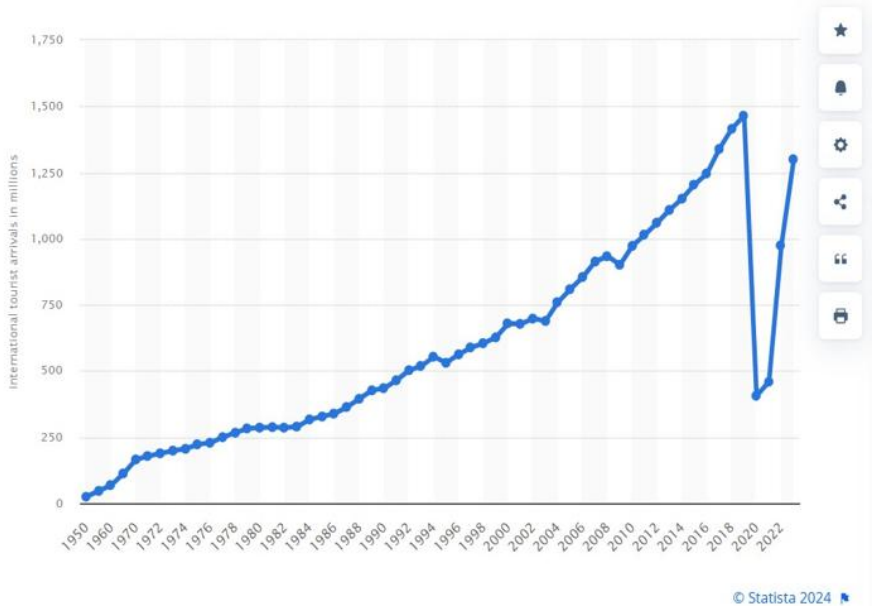

Figure 1. Number of international tourist arrivals worldwide from 1950 to 2023 (in millions)

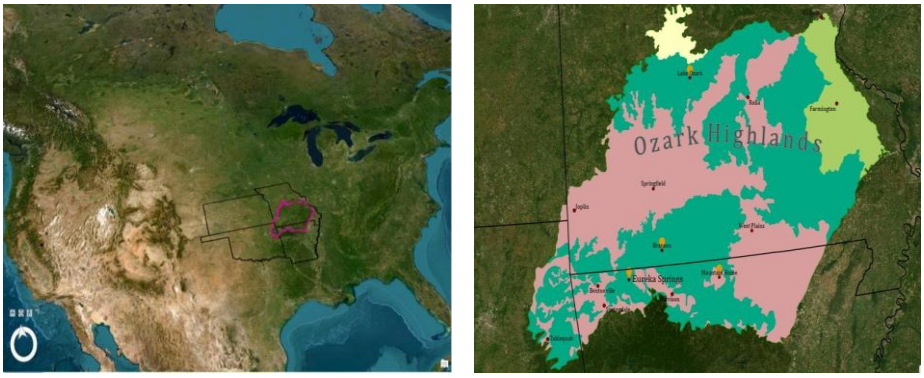

Figure 2. Image demonstrating the outline of the Ozarks region as compared to the United States, map outline of the Ozarks demonstrating varied terrains of the area

Tourism amenities of the ozarks

The prevalence of karst topography in the Ozarks has contributed to the physical uniqueness and aesthetic appeal of the area as well as the development of its cultural history. The bedrock of the Ozarks primarily consists of limestone and dolomite, creating porous surfaces that are prone to the development of karst formations such as caves, sinkholes, and springs.

The cultural history of the Ozarks may have begun as early as thirteen thousand years ago, during the waning stages of the last ice age. The discovery of pre-Clovis and Clovis era tools in and near the Ozarks is thought to be an indicator of the presence of Paleoindians, who may have had seasonal migration patterns in the area. Archeological evidence has shown that archaic era natives used bluff caves in northern Arkansas, especially along the Buffalo River, as shelters and to store food (Arkansas Archeological Survey, 1:35-19:39). In the Historic Cultural Period of archaeological Native American History (from 1670AD to the present), the Osage tribes were the most populous in the Ozarks. At present, there are no federally recognized tribes in the Missouri or Arkansas portions of the Ozarks, but that has not reduced the impact on cultural identity in the region. There are several recognized tribes in the Oklahoma Ozarks, where many Native Americans were relocated in the 18th and 19th centuries.

Early settlers in the Ozarks learned to survive by utilizing the resources the land provided. In the densely forested hills of the Ozarks, log cabins were a popular choice for initial shelter and land had to be cleared for crops and livestock. Many supplies, such as clothing, tools, and furniture, were made by hand (Shiloh Museum of Ozark History, n.d.). Most early settlers preferred to build their homesteads on flatter, or terraced, portions of the Ozarks, either on the plains or near wider sections of rivers where floodplains left rich alluvial deposits, making the land fertile for planting crops. There were those, however, who lived a more independent and secluded lifestyle in the hills. These settlers were more likely to form their own economic circles with other hill communities in which trade was the predominant currency (Stevens, 2005) and represent the “hillbilly” culture that emerged in the Ozarks. This cultural sect is often thought to have an antiquated sociocultural structure that persisted because of that geographical isolation.

This history provides many learning opportunities that current residents can utilize to increase interest in cultural and historic tourism. Even with the advent of technology, there are still several things that have not changed, culturally speaking; modern culture in the Ozarks is defined generally as one that is politically conservative, dependent on Christianity, has many values based around family connections, outdoor experiences like hunting and fishing, and protecting their way of life. Many communities in the region have developed a tourism industry, whether small or large. For some it is as simple as being known for having various flea markets while, in other communities, there are shows, theme parks, haunted historic hotels, a plethora of shopping and dining options.

Literature Review

Overtourism affects destinations all over the world and has been studied extensively, but particularly in European destinations (Mihalic, 2020; McKinsey and Company, 2017; Milano *et al.*, 2019; Szromek *et al.*, 2020; Mandic *et al.*, 2021). While the term “overtourism” has only emerged in recent years, the concept, and the need to act, has weighed on popular destination communities around the globe since travel has

become more accessible and expanding crowds more imminent. Throughout the late 20th century until present day, ideas have been formulated and tested to try to make tourism more sustainable, though the paradigm of sustainable travel has undergone many changes as new research leading to more advanced information has emerged. A problem that is often found when attempting to mitigate or prevent overtourism is that different stakeholders tend to take opposing positions. "Stakeholders", in this study, refers to destination community residents, businesses, organizations, tourism agents, and government entities in addition to the destination's tourists. Business owners, for example, are more likely to deny the problem because they are profiting from it, whereas residents, whose daily lives often become disrupted by excessive tourism, will likely be more inclined to want to take action (Mihalic, 2020). The willingness of stakeholders to acknowledge that a problem exists can also be related to the type of destination, as places that are already expected to be crowded are less likely to be perceived negatively for being overcrowded. "…tourists visiting Disneyland or New York are expected to be more tolerant to (or attracted by) crowding than people who travel to other destinations offering attractions related to natural resources, such as beaches or forests." Furthermore, research in the Canary Islands measured the impact of population density and environmental services available on several islands and found that there was a negative correlation between higher population densities without improved services and updated infrastructure on tourist satisfaction (Santana, Hernandez, 2011).

Even once stakeholders have become aware of the problems that overtourism brings to their community, mitigation strategies that keep a destination sustainable (and stakeholder content) can be hard to achieve. Some common tools that are used are pricing tools, promoting travel to other locations in the area, establishing regulations on tourism, educating tourists, incentivizing tourists to arrive in nonpeak seasons, and establishing capacity limits (McKinsey and Company, 2017). Some of these solutions can be controversial, however, as some stakeholders will benefit more than others. Pricing tools can help limit the number of arrivals, but questions arise as to whether it is ethical to reduce access to recreational opportunities by charging more and potentially alienating those from lower socio-economic classes from the educational and experiential opportunities of a destination. Promoting travel to other locations would be beneficial to the affected community as well as surrounding communities, but business owners in the original destination may not reap the same benefits. Tourists who enjoy spontaneity may be less likely to travel to a destination if it requires reservations. Some amount of discontent is an unavoidable necessity, however, such was the case in Venice, where cruise ships were disallowed and tourism fees, along with smart turnstile entries at popular locations, were implemented in the summer of 2022 (Visitvenezia, 2022).

In Barcelona, overcrowding has led residents to develop grass-roots campaigns to decrease peak season tourism and distribute tourist arrivals more evenly throughout the year, though some involved in the movements would just like to see less tourism in general. This comes on the heels of exponential visitor increases that have caused various complications for permanent residents of the city. The organizations responsible for maintaining the grassroots movements seek to promote the "degrowth" of tourism through participating in decision-making for issues such as housing affordability, cost of living, and tourist arrivals (Milano *et al.*, 2019). In Krakow, a study has shown that residents of the city generally had somewhat positive view of tourism to the city, although results from the main tourist region of Stare Miasto showed lower levels of contentment. Included in the assessment were general residents and businessowners. The businessowners, understandably, had a much more positive perception of tourists

than did general residents, underscoring the differences in needs, and therefore potential conflicts in selected methods of overtourism mitigation, of different types of stakeholders (Szromek, 2020).

Ultimately, though, the residents of a tourism-oriented community can increase, uphold, or break the desirability of a destination. It is the residents that maintain the stability of critical infrastructure, such as emergency services, education, and health services. It is the residents that can create a sense of social cohesion and, therefore, cultural interest that is attractive to tourists. As one study states, "Therefore, local communities' well-being needs to be put into the centre of tourism initiatives and operations… Responsible tourism focuses entirely on the benefits it provides for local communities in sociocultural, economic, and environmental aspects (Mandic, 2021)." The economic disparities, excessive traffic and noise, increased cost of housing, and environmental degradation that can occur due to overtourism are issues that can drive residents away, creating economic instability, lack of resources, both natural and in critical infrastructure, and lack of cultural awareness, among other things, leading to decreased tourist value and a downward spiral for the affected community.

Methodology

The Ozarks spans a large geographical area that includes various communities, which would make it difficult to obtain data for one study of this scope. Interviews conducted in May, 2019 (pre-covid) by Dr. David R Perkins engage with tourism leaders in four Ozarks communities. The interview protocol asked a series of questions to the local tourism officials regarding tourism and 'overtourism'. The concept of overtourism was defined according to the definition adopted by the Center for Responsible Travel (CREST) and fully explained prior to any questioning regarding the topic (see appendix). Interviews were given over the phone, recorded, and transcribed. These communities involved in this study include Lake of the Ozarks, Missouri, Branson, Missouri, Eureka Springs, Arkansas, and Mountain Home, Arkansas (Figure 2). These interviews are reviewed to help determine risk factors for overtourism, past and present. Next, demographics of each of the communities will be examined to better contextualize how tourism may interface with the local areas of interest, further providing insight into a potential for social vulnerability to overtourism. To preserve anonymity, the names and positions of the interviewees are omitted from the paper.

For the demographic analyses, Census data is analysed for the variables percent of those 16 and older that are participating in the workforce, gender equity in pay, percent of population in poverty, potential participation in the tourism industry in occupations, and population over 65. Subsequently, these same statistics will be compared to those of their respective states to examine whether they are out of the ordinary for the state in general, hence making it more likely that the tourism industry has influenced the community. While the chosen statistic to represent tourism industry worker percentage (that is the percentage of workers involved in Arts, entertainment, and recreation, and accommodation and food services, as stated by the Census Bureau) does not necessarily represent only tourism workers, it is the closest statistic that reflects tourism activities and, therefore, would be the most representative of tourism workers.

Results and Discussion

The Ozarks is a unique area that offers a veritable treasure trove of recreational opportunities for tourists and residents alike. That being said, tourism is not without its obstacles in this region, namely the risks

associated with overtourism. Based on the interviews, leadership has a tendency to deny the existence of the symptoms of overtourism, though key concepts are discussed that would support the theory that overtourism either exists or has existed in all four communities.

Lake of the Ozarks, Missouri

Lake of the Ozarks, Missouri is a small town in central Missouri that is located on the banks of the manmade lake, Lake Ozark. The lake was created by two dams and draws many tourists, mainly for water recreation, the scenic location, and shopping. The population was 2,355 as of the 2021 Census 5-year estimate.

Interview

We interviewed a top tourism official at Lake of the Ozarks in May, 2019. The interview summarily revealed that the town is dependent on tourism revenue and that there have previously been struggles to maintain both resident and tourist satisfaction. This is particularly the case regarding motor vehicle traffic and economic stability (seasonality). According to the interviewee, government funding was used about 15 years ago (around 2004) to establish a 7-mile bypass to divert traffic away from main tourist attractions. Doing this also opened an East-West corridor for cross-state traffic to switch creating further accessibility to driving tourists, who make up the majority of tourists to the area. Economic conditions often suffer as a result of overtourism, which is supported by the city representative.

Ozarks: “Tourism at Lake of the Ozarks is discretionary dollars. As the economy gets tight… you see a shift… you see people maybe not staying as long as they normally would stay.” alternatively, “People may say, instead of going to California or Florida, or out of the country or whatever this year for our vacation, we’re going to go to Lake of the Ozarks because it’s more affordable.”

Complications as a result of the seasonality of tourism are common in communities affected by overtourism, “The school start date has really affected us. The season was from Memorial Day to Labor

Day… over the last 20 years we’ve seen schools starting now in the first or second weeks of August… August used to be our most powerful month for visitation and now the second week of August, all of the families are gone… so we kind of lost some of that summer vacationing.” The community looked for a solution to the dependency on the short peak season that began in late May and ended mid-August.

“Sports travel has become something that has really taken families away from the traditional… vacation… and they’re having to travel a number of times a year to participate in those sporting events and it’s taking away from some of their vacation time.” This propelled the community to adopt the idea to take advantage of sports travel. Eventually, a vote was taken to raise lodging taxes and use the resulting funds to construct and operate a new soccer complex that would attract travelers throughout much of the year.

Demographic analysis

About 62% of the workforce-aged population in Lake of the Ozarks is actively participating in the workforce as of 2021 (Figure 3), which is the highest of the four communities that were analysed,

however, this community had the lowest gender equity in pay of all four communities, with a discrepancy of over $28,000 (Figure 4). Over 18% of the population fell into poverty-level income (Figure 5). Just over 13% of the workforce has an occupation labelled as "Occupation in Arts, entertainment, and recreation, and accommodation and food services Industry", indicating the potential to be involved in the tourism industry, and 26.2% of the population is 65 years old or older (Figure 6). The large population of individuals that are age 65 plus, compared to the state average of 17.6% and the country average of 16.8% (Figure 7), may explain the slightly lower percentage of workforce-aged people who are actively employed (62.8% for Missouri, 63.5% for the USA), however, the inequity in pay by gender and poverty levels suggest that there is an underlying issue in the composition of the economy in Lake of the Ozarks that can, at least to some extent, be corrected by managing tourism more sustainably.

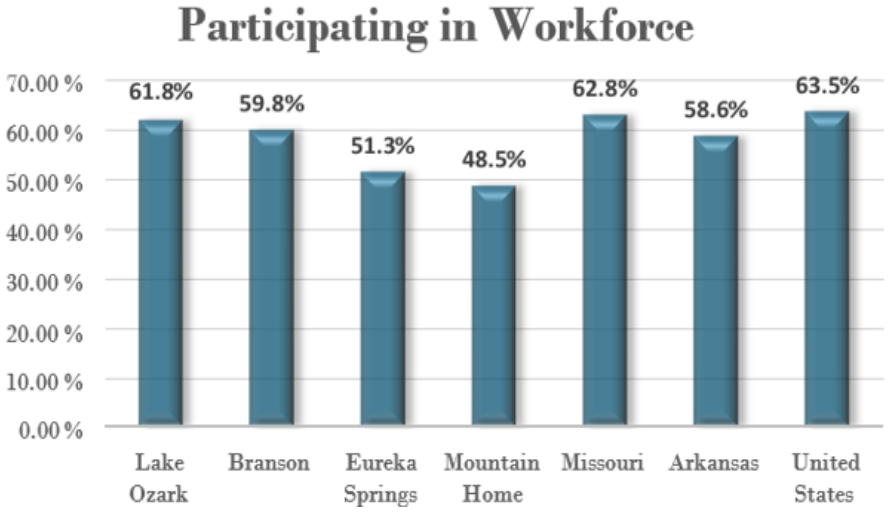

Figure 3. Chart showing the differences in % of working-aged residents that are actively engaged in the workforce between all study communities, their respective states, and the United States of America

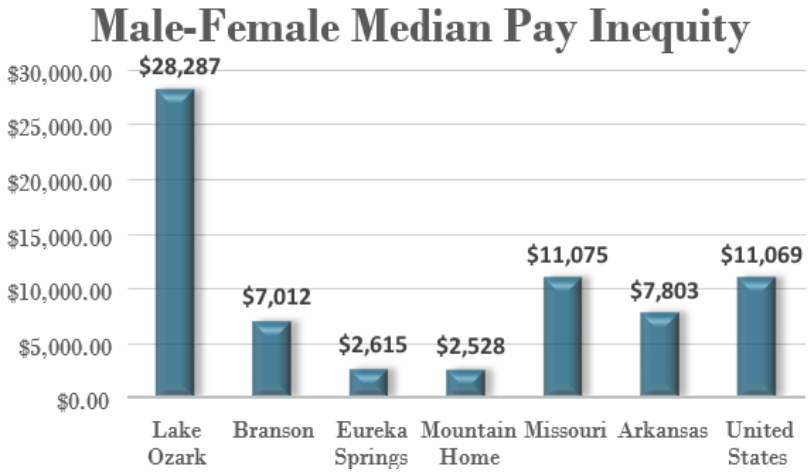

Figure 4. Chart showing the differences in dollar amount of the median pay disparity between males and felames in all study communities, their respective states, and the United States of America

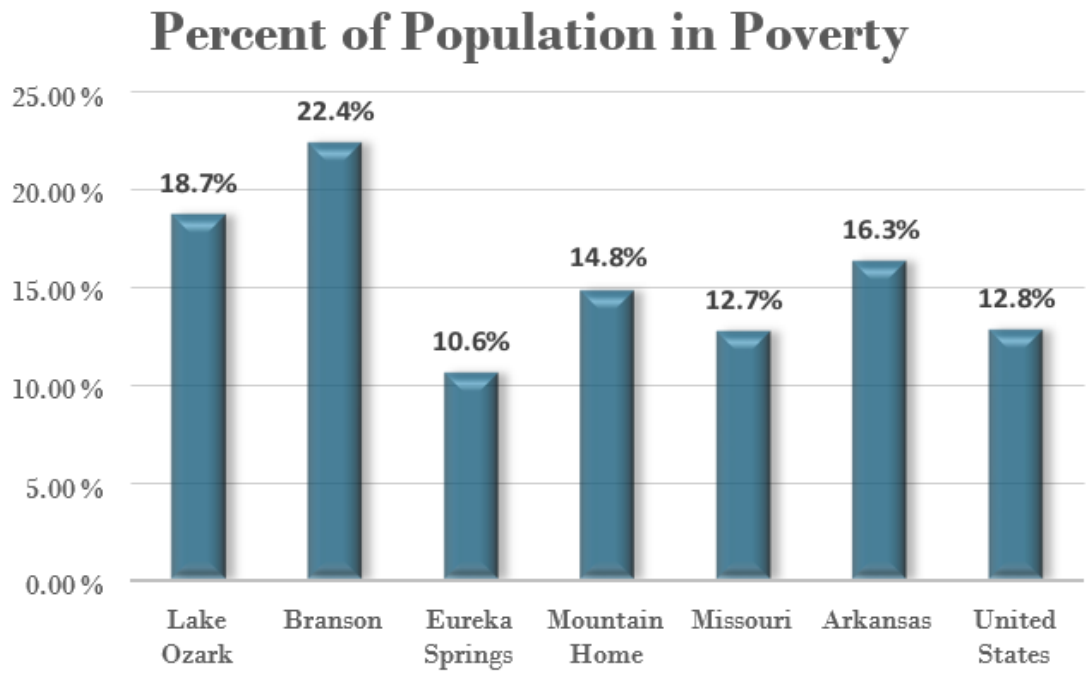

Figure 5. Chart showing the diffrences in % of residents whose income falls beneath poverty levels in all study communities, their respective states, and the United States of America

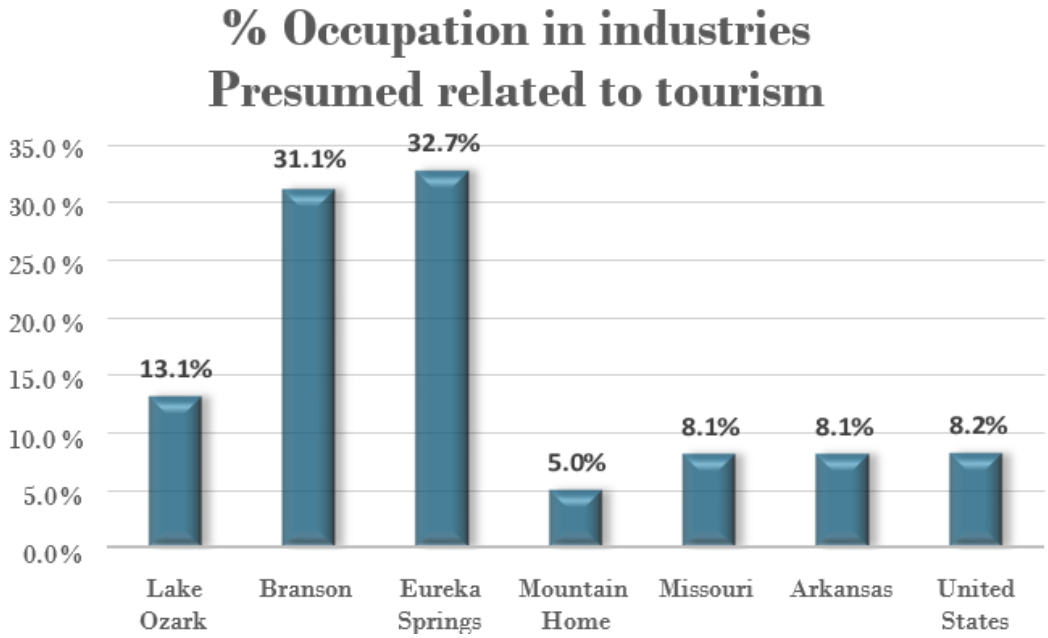

Figure 6. Chart showing the diffrences in % of residents who are engaged in occupations in the arts, entertainment, and recreational and food and services in all study communities, their respective states, and the United States of America

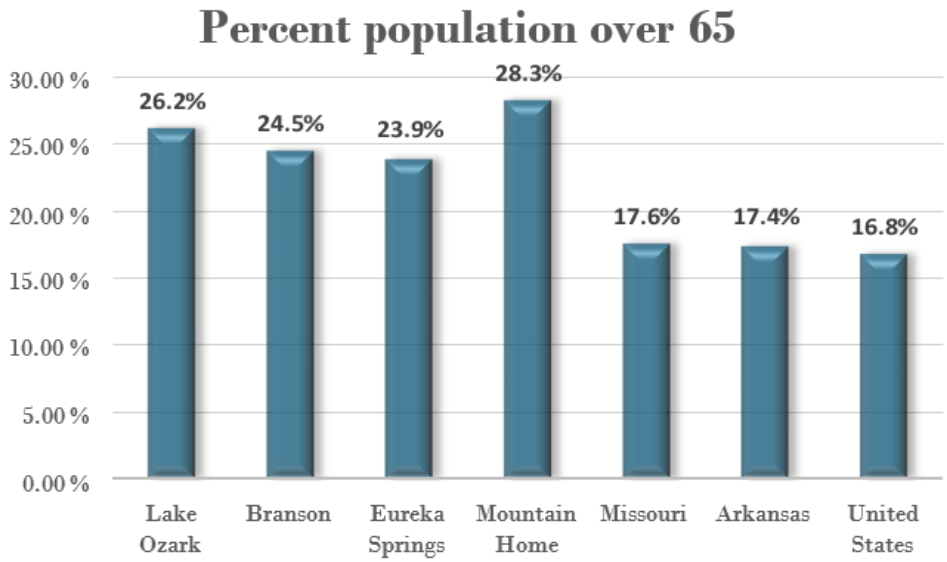

Figure 7. Chart showing the diffrences in % of residents who are age 65 and older in all study communities, their respective states, and the United States of America

Branson, Missouri

Branson, Missouri is a small town located in southwestern Missouri. This town has historically oriented towards music, shows, plays, and cultural tourism elements such as miniature golf, water parks, museums, go-karts, arcades, shopping, and dining. As a town within the rolling hills of the Ozarks and with direct lake and river access, it is becoming increasingly focused on outdoor nature-based tourism and recreation. The population of Branson was 12,579 as of the 2021 Census 5-year estimate.

Interview

As with Lake of the Ozarks, we expected to find a high degree of dependency on tourism dollars in Branson, Missouri. The local tourism official representing Branson, Missouri revealed that the town is highly dependent on tourism revenue and has, until the time of the interview (2019), found success in the industry. The interviewee downplayed concerns about overtourism, but evidence shows that there have been related problems, such as impacted infrastructure. For example, it was stated that there was a time when the local Highway 76 was so congested that it was dubbed a “parking lot” by many. Action was taken and a colorcoded alternate route system was constructed to divert traffic from the highway. It was also said that the Branson area has been hit with several disasters and tourism was quite weather-dependent, “We have learned since our very first flood… we had 500-1,000 years floods between ‘09 and ‘15, repeating each spring… and it was daunting… We put together a crisis communications team… and we had the Weather Channel here [letting people know] that we are open for business.”

With overtourism, there is often a loss of sense of place as outside influences make their way into a community. Branson has not been an exception to this. When asked about whether Branson was a

gateway destination or a destination unto itself, the interviewee responded by saying that several area communities were working together to promote the Ozarks as one broad destination.

Demographic analysis

In Branson, about 60% of the workforce-aged population is actively participating in the workforce as of 2021 (Figure 3). The town has a disparity in gender equity in pay of $7,012 (Figure 4), a number that is significantly lower than the state average of $11,075 and the USA average of $11,069. A total of 22.4% of the population fell into poverty-level income (Figure 5). Over 31% of the workforce has an occupation labelled as "Occupation in Arts, entertainment, and recreation, and accommodation and food services Industry" (Figure 6), indicating the potential to be involved in the tourism industry. This percentage is much higher than the state and country averages (8.1% and 8.2%, respectively). Finally, 24.5% of the population is 65 years old or older. The large population of individuals that are age 65 plus, compared to the state average of 17.6% and the country average of 16.8% (Figure 7), may explain the slightly lower percentage of workforce-aged people who are actively employed (62.8% for Missouri, 63.5% for the USA). Additionally, the lower disparity in income equity in conjunction with the percentage of workforce participation in potential tourism-related activities could indicate that tourism does help to alleviate this issue, however, the comparatively high percentage of the population that is in poverty (12.7% for Missouri, 12.8% for the USA) indicates that the tourism industry in this location is not being equitably used across the community.

Eureka Springs, Arkansas

Eureka Springs is a small town located in northwestern Arkansas. While it is near several lake communities, the only water features within town are the springs for which the town is named, which are thought to have healing properties. Tourists here are drawn to the historic, narrow, hillside streets offer culturally eclectic shopping and dining. There are also several natural areas nearby for outdoor enthusiasts and, more recently, staged shows have begun to make a comeback to the town. The population was 2,159 as of the 2021 Census 5-year estimate.

Interview

Eureka Springs was also found to be highly dependent on tourism revenue, which was supported by the local tourism and business representative who revealed a very strong dependency on tourism: "Eureka Springs only exists as [a result of] tourism… There would be literally no commerce here" without tourism. In addition, our interviewee indicated that overtourism had been prevalent in the town in the past, mainly in the 1980s-1990s. During this time, legislation was passed restricting the use of homes as sources of lodging to help prevent strain on residential housing availability. Our interviewee noted: "A difficult thing for Eureka Springs specifically is that we're kind of isolated like an island out here… we don't have any true population density tacked onto us. We're depending on everybody driving here." It was found that this dependency on tourists who drive to the town also culminated in overtourism symptoms when, in the same timeframe noted above, group travel via bus was a popular mode of tourism. The narrow streets of the historic town were "scarcely able to accommodate the large vehicles, resulting in damage to roadside retaining walls, severe traffic congestion, and stains on buildings from exhaust emitted from the

buses." The town acted again, in this case ensuring that buses would need permits to access the downtown area.

Demographic analysis

In Eureka Springs, Arkansas, about 51% of the workforce-aged population is actively participating in the workforce as of 2021 (Figure 3). The town has a disparity in gender equity in pay of $2,615 (Figure 4), a number that is very significantly lower than the state average of $11,075 and the USA average of $11,069. A total of 10.6% of the population fell into poverty-level income, which is significantly lower than the state average of 16.3% and lower than the country average of 12.8%, indicating a healthy economy. (Figure 5).

Nearly 33% of the workforce has an occupation labelled as "Occupation in Arts, entertainment, and recreation, and accommodation and food services Industry" (Figure 6), indicating the potential to be involved in the tourism industry. This percentage is the highest of the four communities and is much higher than the state and country averages (8.1% and 8.2%, respectively). Finally, 23.9% of the population is 65 years old or older. The large population of individuals that are age 65 plus, compared to the state average of 17.6% and the country average of 16.8% (Figure 7), may explain the significantly lower percentage of workforce-aged people who are actively employed (62.8% for Missouri, 63.5% for the USA). Additionally, the lower disparity in income equity in conjunction with the percentage of workforce participation in potential tourism-related activities could indicate that tourism does help to alleviate this issue. Economically, at least, tourism in Eureka Springs appears to be occurring sustainably.

Mountain Home, Arkansas

Mountain Home is a small town located in north-central Arkansas. The town is the largest populated area that is situated between Norfork Lake and Bull Shoals Lake, drawing many tourists for fishing and water recreation. The population was 12,722 as of the 2021 Census 5-year estimate.

Interview

In studying the community of Mountain Home, we found that overtourism had a lighter, but still noticeable impact, especially in the lodging industry. The interview with the local tourism official indicates that, in spite of the lower influx of tourists than other focus communities, the town has also faced overtourism symptoms: "The biggest changes we have observed are the use Airbnb and VRBO properties to stay… it's making our hotels and resort people rethink the way they market themselves and… relook [sic] at the whole way they're doing business… It is putting our existing hotels and resorts in a bit of a bind that they just don't seem to be seeing as many bookings as they've had in past years."

Demographic analysis

In Mountain Home, Arkansas, 48.5% of the workforce-aged population is actively participating in the workforce as of 2021 (Figure 3), which is the lowest percentage of the four communities examined. The town has a disparity in gender equity in pay of $2,528, the lowest of the four communities (Figure 4) and a number that is very significantly lower than the state average of $11,075 and the USA average of

$11,069. A total of 14.8% of the population fell into poverty-level income, which is lower than the state average of 16.3% and higher than the country average of 12.8% (Figure 5). Only 5.0% of the workforce has an occupation labelled as "Occupation in Arts, entertainment, and recreation, and accommodation and food services Industry", a figure that is indicative of the community's potential to be involved in the tourism industry. This percentage is the lowest of the four communities and is much lower than the state and country averages (8.1% and 8.2%, respectively) (Figure 4), indicating that the community is not strongly economically dependent on tourism. Finally, 28.3% of the population is 65 years old or older (Figure 5). The large population of individuals that are age 65 plus, compared to the state average of 17.6% and the country average of 16.8%, may explain the significantly lower percentage of workforce-aged people who are actively employed (62.8% for Missouri, 63.5% for the USA). Additionally, the lower disparity in income equity in conjunction with the percentage of the population that is age 65 or older could indicate that there is a high prevalence of retired individuals.

Conclusion

The results of this study show that overtourism can impact communities of all types, no matter how dependent the community economy may or may not be on tourism. Based on the interviews of community leaders, it appears that there is a majority focus on the economic benefits of tourism rather than benefits to the community as a whole. Most interviewees seem to brush resident concerns off, although there has been past activity that has improved quality of life for residents in most. In spite of appearnaces, further studies would need to be conducted to make a connection in the roles of key stakeholders in the development of the tourism industry and risk of overtourism in each community. Demographic analyses reveal a tendency for tourism communities to have larger than average populations of retirees in residence, as all four communities had higher percentages in this category than state or country averages, though whether this is because the location attracted residents of retirement age who then partook of the tourism industry or whether the tourism industry attracted the retirees is undetermined in this study. Overtourism symptoms, whether past or present, were indicated in all four communities.

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Appendix: Interview transcript protocol

This chapter will examine the increase in tourism since the 1950s and the range of management practices employed, the abrupt rise in tourism over the last decade, culminating with the usage of the term "overtourism," defined by CREST as:

"tourism that has moved beyond the limits of acceptable change in a destination due to quantity of visitors, resulting in degradation of the environment and infrastructure, diminished travel experience, wear and tear on built heritage, and/or negative impacts on residents."

Overall assessment of tourism

- What recent changes have you observed regarding tourism in [place name]?
- Have you observed any positive impacts resulting from tourism in [place name]? Please explain
- Have you observed any negative impacts resulting from tourism in [place name]? Please explain
- If tourism were developed or increased in [place name] in what ways do you think it would change [place name]?

Overtourism questions

- There is a concept called 'overtourism' and I am interested in your interpretation of it. I will define it for you and then ask you a few questions specific to [place name].

Over tourism is "tourism that has moved beyond the limits of acceptable change in a destination due to quantity of visitors, resulting in degradation of the environment and infrastructure, diminished travel experience, wear and tear on built heritage, and/or negative impacts on residents."

- Do you feel that there are times of the year where [place name] may experience overtourism? Please explain
- As a result of an excessive quantity of visitors (tourists) do you think [place name] has experienced environmental degradation? Please explain
- As a result of an excessive quantity of visitors (tourists) do you think [place name] has experienced degradation of the local infrastructure? Please explain
- As a result of an excessive quantity of visitors (tourists) do you think the tourists themselves in [place name] have had their 'experience' negatively affected? Please explain
- As a result of an excessive quantity of visitors (tourists) do you think the local residents of [place name] have experienced any negative consequences? Please explain

Submission ID: 157

International, National and Local Linkages for Sustainable Tourism: Case Studies of Sherpas in Nepal and Touristic Activity Groups of Tunceli, Turkiye.

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Abstract

Touristic activities can be arranged and organized in different frames, such as normal times and COVID times have shown recent differences. However, they may also differ in the purpose of the activities: leisure time or scientific activities. Sustainability of tourist activities requires interconnectivity of local, national, and international relations. This paper derives findings through the literature on the Sherpas in Nepal in the environs of Everest and touristic leisure time activity groups of the Tunceli province and the Munzur National Park areas. The Sherpas are important for the achievement of Everest-related activities. Their physical conditions for climbing higher altitudes are valuable as guides for coming climbers and scientists. Their self-organization transferred them to touristic company owners and action organizers in time. However, the situation in Tunceli was slightly different. The locals started to prepare trekking and walking groups around the Munzur National Park. These local activities evolved into organizations' national and international activities. Their context is useful for religious and environmental leisure time activities. The activities and their organizations can be followed in actual life and the cyber World. Although both groups' activities are on a touristic base, their presence is essential for controlling and sustaining their local environments in normal and chaotic situations. This paper reveals the importance of locals' actions for their environment's sustainability whatever the origins or awareness levels of tourists arriving in their areas.

Introduction

Touristic activities can be arranged and organized in different frames. The touristic activities of normal times and COVID times have shown recent differences. However, they may differ in the purpose of the activities as well: leisure time activities, scientific activities, social control, aid, and social pressure group activities. Sustainability of tourist activities requires interconnectivity of local, national, and international relations.

Mountains, oceans, rivers, forests, and many more places and their environs require protection for present generations and generations of the future. The present research focuses on two mountains and people in their environs: Mount Everest, Nepal, and the Munzur Mountains and Munzur National Park, Türkiye. Everest and its environment received great interest from researchers over the years. However, Tunceli and Munzur National Park did not receive that much interest in earlier times. Both mountains are at different altitudes. The Munzur Mountains are 3300 and the Mount Everest is 8849m. The Munzur National Park follows the Munzur River in a canyon that leads to Munzur Mountains. The comparison of both case studies is not in the frame of numbers but rather the development of their relation to nature and humans, balanced or unbalanced relationships with ecosystems. Local communities of Sherpa played an important role in the achievements of the Everest-related activities. The locals' physical conditions to

climb higher altitudes are better than the coming climbers and scientists have placed them differently in the area. But then, their self-organization transferred them to touristic company owners and action organizers in time.

However, the situation in Tunceli was slightly different. The locals started to prepare trekking and walking groups around the Munzur National Park. These local activities evolved into organizations' national and international activities. Their context is useful for religious and environmental leisure time activities. The activities and their organizations can be followed in actual life and the cyber World.

Although both groups' activities are on a touristic base, their presence is essential to the control and sustainability of their local environments in normal and chaotic situations. This paper reveals the importance of locals' actions for their environment's sustainability whatever the origins or awareness levels of tourists arriving in their areas. The adaptation strategies adopted by the Indigenous community are important for their resilience against the increasing impact of climate change and depend on their perception of climatic changes and social and environmental structures.

Literature Review

There is a vast amount of literature about valuable ecosystems the necessities of protecting them and the roles of communities in the governance of their environs. This issue was ignored and recently, the importance of awareness, participation, and partnership come to forward. Different regulations to protect the ecosystem have been coming forward in time, one of them is the Kunming-Montreal Global Biodiversity Framework. «Countries' differentiated responsibilities to fulfill area-based conservation targets of the Kunming-Montreal Global Biodiversity Framework» (Shen *et al.*, 2023). See Figure 1 used by Shen *et al.*

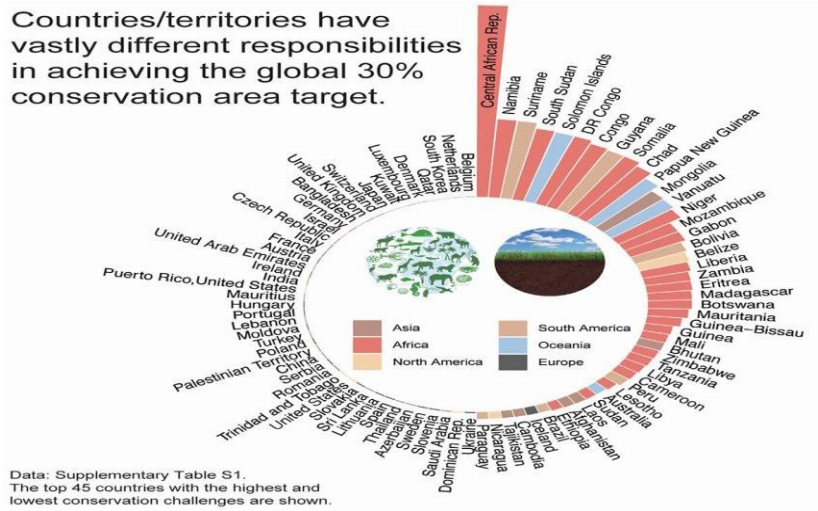

Figure 1. The Kunming-Montreal Global Biodiversity Framework.

Source: Shen *et al.*2023

As Shen and friends mentioned, «Countries will need to take cooperative and coordinated action at a Global scale, supported by strong funding mechanisms, to ensure that the 30% conservation area target

of the Kunming-Montreal Global Biodiversity Framework is equitably and effectively achieved by 2030». (Shen *et al.,* 2023).

In this figure, since we are looking at two cases Nepal and Turkey, we can see Turkey but not Nepal. However, there are questions to be answered: how much these goals will be achieved and what are the impacts of factors (in and out) that can be discussed? As Zang and friends put forward there are influential factors and their interactions should not be ignored.

Zhang, Tian, Long, Li, and Wu were paying attention to the mass tourist activities, rescue methods, and impacts of disasters on them by taking the Wenchuan earthquake as an example from China. They were using 16 assessment indicators. The top five were management systems, publicity and education, regional emergency planning, prompt notification, training, and emergency drills.

They revealed the interconnection of multiple factors, such as productivity development and largescale exploitation and utilization of natural resources in the 1960s and 1970s. The intention is to bridge and narrow attempts with the gap between the developed countries of the West. They have pinpointed that these attempts caused the achievement of development but resulted in serious ecological problems. They were paying attention to disruptions, and material transformation between man and nature. The most important thing for them is the necessity of increasing awareness. That is related to "how to coexist and co-prosper with the earth to maintain ecological balance, protect safe and diverse ecosystems and create a safe, healthy and comfortable living space, and are committed to realizing an ecotourism system with sustainable development as its goal" (Zhang *et al.,* 2023).

To achieve this balance by considering SDGs brings to mind Kruse and friends' study output of five countries and community resilience to natural hazards. They defined resilience through three interconnected domains of resources and capacities, actions, and learning. For them, these three are influencing integral elements. However, there are extra-community forces such as disaster governance, laws, policies, responsibilities, general societal context, and system change over time, and human-made disturbances have to recognize (Kruse *et al.,* 2017).

So, tourist activities wherever take place, require careful systemic studies, organization, and control in a complex frame to protect the ecosystem without harming nature and people.

Mary B. La Lone revealed the importance of tracing activities, of the social capital networks in the appendices "Unfolding Events and Stages in the Social Mobilization Process during Week 1 Following the Tornadoes" of her study of neighbors helping neighbors (La Lone, 2012).

We can think of tracing social capital networks of touristic activities. Their results might include taking and giving things to nature and communities. So local communities are no longer passive recipients of the influences of the incomers.

Dawson and friends studied conserving biodiversity and the roles of indigenous people (IPs) and local communities (LCs). They have revealed their extended roles beyond participation for more equitable governance. This is based on value and institution recognition and their relative control. They worked on

648 empirical studies. They are intended to develop typology and analyze a sub-sample of 170, came out with an association to ecological outcomes and implications for the Global Biodiversity Framework targets (Dawson *et al.*, 2024).

Within this frame, this study evolves into the following sections: methodology, findings related to the Sherpas, Nepal in the environs of Mount Everest and people in Tunceli and the Munzur National Park environs, and conclusion.

Methodology

This paper derives findings through the literature related to two case studies. Firstly, the Sherpas in Nepal in the environs of Everest. Secondly, touristic activity groups of Tunceli and Munzur National Park areas.

Both groups' activities are based on national parks (Sagarmatha-Mount Everest and Munzur) and related activities. Interviews are ongoing in Tunceli and planned for Sherpa case.

Results and Discussion

La Lone revealed the importance of neighborhood solidarity in community resilience in the study of Neighbours Helping Neighbours. An interesting approach is labeled with the following wordings. «Planning for community resilience to environmental disasters needs to give greater consideration to potentials for response and recovery contributions available through local-level, informal social capital networks, as well as from the more formal policy and planning channels». Mobilizing social capital resources is important (La Lone, 2012). In this respect, the preliminary results of both case studies can be summarized in turn.

Sherpa, Nepal

Sherpa's historical reflections in the literature related to their environs, following dates traced. Klesius begins writing about the 50th year of Everest's history by mentioning Walt-Unsworths wording. "if Mount Everest had been climbed on the first attempt, this success would still be considered important and celebrated, but it would be quickly forgotten. Ironically, it was the successive failures that brought this mountain its real fame" (Klesius, 2003). Klesius summarized 50-year history with milestone important times as follows: 1852, 1865, 1911, 1921, 1922, 1924, 1933, 1953, 1960-61, 1963, 1975, 1980, 1983, 1996, 2000, 2001, 2002 -(2003).

In this historical frame Edmund Hillary, Tenzing Norgay, Urkien, and Edmund Hillary are important names to mention in these above milestones. (Miller, 2003). Activities and changes in the community can be listed as follows:

Miller referred to Frank Smythe's study. "The Kanchenjunga Adventure, 1946". Sherpas were first employed as porters in 1909. According to Miller, Kelas was the employer labeled as the father of Himalayan climbing (1965). Studying communities, helping mountaineering, and clarifying changes in Sherpas and other groups are important according to Gabriel Chevally and Tenzing. The relationship with Sherpas was more than a material contract (Miller 1965).

Edmund Hillary pointed out changes during the time in his writing entitled "My Story" as follows (Hillary, 2003). The visible marks of foreigners were 27 built schools, two hospitals, and 12 clinics (2003). The communications and achievements of climbing high altitudes, and collaborations of locals and visitors evolved in time. Developments of local settlements, establishment of local tourist companies, and transfers to international or national levels become visible over time (Reid 2003, pp.44-71).

Social media and news from related environs have been examplifying disasters and recoveries or finding victims with the aid of local Sherpas through time. Ortner's study examined the deaths of 8 people from 3 different parties, in May 1996 by examination of meanings with referrals to Clifford Geertz, culture, and power. She mentions differences between locals and arrivers and their relations in the frame of culture and power (Ortner, 1997)

Betül Şenkal summarized the experiences of the Turkish climbers namely Nasuh Mahruki and Tunç Fındık's arrival at the summit of Everest. Mahruki known as the "snow leopard" (named by the Russian Mountain Federation) reached the summit on the 17th of May 1995 from the Tibet side route. Following this experience, on the 23rd of May 2001, only Tunç Fındık with Lhakpa Şerpa reached the summit of Mount Everest from the Nepal side route from the 15-person team (2003). Mahruki and Fındık were not the only mountainers or the climbers. But their experiences illustrated a close linkage of personal, international, national, and local influences.

Lionel Obadia was paying attention to conflicts in the study "The Conflicting Relationships of Sherpas to Nature: Indigenous or Western Ecology?" «…to question the parallel transformations of the ecological settings and representations of this ethnic group living in Northern Nepal. …apparent contradictions between Sherpa beliefs and practices are owing both to their culture and to the result of development ideologies that parallel the opening of Nepal to a Global economy. Sherpa conservation practices are 'traditional' as well as infused with Western ideas of sustainability, which the Sherpas have incorporated and reinterpreted» (Obadia, 2008).

These types of investigations about changes in identity, impacts of commodity, necessity, or value of stewardship of Sherpas have become common discussion issues.

As Largent a Ph.D. candidate was examining the ethicality of hiring Sherpas while climbing Mt. Everest. She mentioned 16 deaths of Nepalese Sherpas on 18th of April 2014. Largent revealed ethics issues are complex due to hazards, and exploitations from outside or inside of the group (Largent, 2014).

However, Stevens (1993) indicated a linkage between tourism, change, and continuity in his study "Tourism, Change, and Continuity in the Mount Everest Region, Nepal". Sherpa inhabited Mount Everest area is the center of Himalayan tourism. Increasing tourism in the Sherpa's economy, changes in land use, and culture. As a result of tourism, the standard of living of most of the population has risen without severe environmental or cultural effects. Increasing regional differentiation in wealth, inflation, out-migration, and changes in pastoralism and forest use may have long-term adverse effects.

So, impacts and interactions can be expected and observed in the short, medium, and long terms. Especially the importance of waste management, usage of the forest, and changing structure of settlement have been illustrated in the study of Pawson *et al.* (1984).

Moreover, Bhatta and Chan's study reveals that the current approach to tourism development and planning does not satisfy the objectives of ecotourism. Results do not benefit enough residents and do not reduce the deterioration of built heritage and culture, use of forest resources, and environmental degradation. The local knowledge, skills, and cultural values are important. They have to be integrated and support conservation agendas. Participation of communities and stakeholders is important to promote sustainability (Bhatta and Chan, 2023).

Different climbing routes developed gradually from Tibet, China, and Nepal in the Himalayas and Mt. Everest. A total of 15 camps were placed on them in time as shown with the label of 15 ways to the summit (Swissphoto Agency, National Geographic Maps, 2003).

Tunceli, Türkiye

There were earlier studies about the region but the Munzur National Park was established in the early 1970's. Endemic animals, plants, productions, and given meanings to the ecosystem are important issues. Examples of them can be mentioned namely; honey, dairy products, beans, potato, rainbow trout, the religiously important given meaning to Munzur river, mountain, and environs and accumulated conservation belief of the ecosystem (Öner, 2020).

It has started to be threatened by construction and plans for the construction of forthcoming dams and relocations of local populations (Öner, 2004). They united resistant local groups and NGO collaborations. They got stronger in 2010 and onwards.

İliç mine disaster recently occurred in Erzincan, (February 2024) and drew attention. The disaster area covers the area near to source of the Munzur River and foothills of the Munzur Mountains above the Munzur National Park. Once more the ecosystem and activities of man and nature and the impact of newcomers have become discussion issues. Developers and their development processes took attention. However, other incomers have begun to be powerful for observing groups for the ecosystem and changes in nature through touristic activities on the other side some of them have been accepted as disrespectful groups to nature and local communities with their leftovers, waste, etc.

Activities and changes in the community can be listed as follows:

The present sensitivity and respect of locals for the ecosystem have a long history and it is a «way of life».

This area has an international migration past and has strong connections with relatives and society. People have a wide range of interactions and connections at the international and local, national levels. People who originated from the region have strong roots and long-term relations at face-to-face or digital levels with the locals.

Terror has been an important interfering issue (Öner 2007, 2008) similar to Sherpa's region and conflicts. However, this region has been much more peaceful for a long time.

Tunceli is in between the North Anatolia Fault and the East Anatolia Fault. Besides this, recent quakes occurred at the Eastern Anatolia Fault and forthcomings are expected on the North Anatolia Fault and its crosssection the other.

Recent studies emphasize rare materials, dam constructions, resistances of locals and disasters, risks and hazards of the region and developments, and investments. Strong networks and knowing the ecosystem, locals, and environs are important.

Recently a disaster occurred in the northern part of the gold mine in İliç, which is above the core source of the Munzur River and Munzur mountains, and the ecosystem is affected. Awareness is increasing. They are trying to measure the impact. Some of the non-governmental groups were active in the protection of locals. Some of the activists' entrance to the disaster area was limited. There have been violent mining activities recently.

Social pressures from locals have stopped some of the hydroelectric dam construction plans.

Information gathered from touristic groups in the Tunceli Province from the field can be mentioned as follows:

Munzur Zirve Dağcılık ve Doğa Sporları Kulübü (MUDAK), TUDAK, Munzur Adrenalin, Infotours, daily tours like prepared by Deren Turizm, Buluş Turizm and Çoklar etc. There are visits of international hunter groups. Some of them conflict with the conservation approach to saving the mountain deer.

However, locals are worried about ongoing tourist activity and their impacts. Endemic plants and rare animals (Brown bear, deer-locally called Bezuar, pink rainbow trout, partridge locally called Ur) in the national park are believed to be saved. Uncontrolled or informal touristic activities are monitored by non-governmental organizations such as the Munzur Environmental Protection Association and governmental organizations and institutions.

Similar to the Everest region new routes developed gradually in the Munzur National Park. In 2020 a feasibility report has recently been prepared by the Fırat Development Agency for the Republic of Turkey, Ministry of Industry and Technology. That report includes hotels, province call centers, and areas. They will be developed further (Fırat Development Agency, 2020)29. Silkworm breeding and cocoon production, Tunceli garlic production, and thermal hotel investment 21 trekking routes can be followed in Fıratı keşfet.com web page in the coverage of the TRB1 regional project (Fırat Kalkınma Ajansı, 2024).

Incoming tourists have valuable contributions to creating social capital networks to consume organic products of the region (as observed in Ovacık and Hozat cooperative studies) and contribute benefits of the area. For these results, face-to-face connections during visits to the region or participation in the annually prepared Munzur National Festivals or through social media agents (Öner, 2023). However, their short stays in the area have been seen as an economic loss and a problem.

Above mentioned complex examples present the necessity of thinking together some international agreements and implications of development processes and, the role of touristic activity groups (touristreceiving communities or touristic groups). It is necessary to observe the goals and their linkages between UN SDGs 2030 and the Sendai Framework for Disaster Reduction as in Figure 2.

Figure 2. Connection necessity between the UN Sendai Framework for Disaster Reduction and SDGs 2030
Source: UNDRR Seven Targets to Achieve by 2030 (2020) and UN Sustainable Development Goals (2020)

Conclusion

Preliminary findings are presented here, and derived detailed findings will be evaluated in the future. However, the following can be spelled out here. Knowing the environment and using it without harming it with a high awareness level is important for both cases. Although both group activities are on a touristic base with different manners, their presence is essential to the control and sustainability of local environments in normal and chaotic situations. They have similarities and differences. They require more studies to understand present communuties, the environment, and ecosystems. The adaptation strategies of indigenous communities are important for the resilience of the communities. Moreover, tourist activities require careful monitoring and acting accordingly as well.

Acknowledgement

This paper has been presented online at the 30th ISDRS Annual Congress, Nepal. The study is still ongoing and this paper reveals preliminary results.

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Track 5 Sustainable Production, Consumption, and Innovation

5a. Corporate Sustainability and Corporate Social Responsibility

Abstracts

Submission ID: 154

Has the Environmental Information Disclosure Policy in China Promoted Green Innovation Among Heavily Polluting Listed Companies?

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Abstract

According to Stakeholder Theory and Signaling Theory, environmental information disclosure policy can transmit a positive signal to stakeholders that companies are actively fulfilling their environmental responsibilities. This further mitigates information asymmetry and agency problems, enhances social reputation of the companies, and enables them to better access the economic resources needed for green innovation. Based on this, this paper investigates the impact of environmental information disclosure on green innovation in heavily polluting companies, which carries practical significance for promoting the green transformation of such enterprises.

China introduced the Measures for Environmental Information Disclosure (Trial) in 2007, which clearly stipulated that companies should proactively disclose 17 categories of environmental information to the public. Additionally, the Guidelines for Environmental Information Disclosure of Listed Companies (draft for comments) issued in 2010, as well as the Measures for the Management of Legal Disclosure of Enterprises Environmental Information introduced in 2021, further clarified the primary responsibility of heavily polluting companies in disclosing environmental information and mandated them to regularly disclose such information. This paper takes all A-share listed companies in heavily polluting industries from 2008 to 2022 as research samples to examine the relationship between environmental information disclosure and green innovation of heavily polluting enterprises. The total sample size of this study is 7113.

The study found, firstly, that environmental information disclosure can significantly promotes green innovation in heavily polluting companies. Results of mechanism testing confirm that environmental information disclosure promotes green innovation of enterprises through alleviating financing constraints. Secondly, environmental backgrounds of executives, analyst coverage, and media scrutiny demonstrate moderating effect on the relationship between the two. Executives with environmental backgrounds, along with analyst coverage and media attention, enhance the beneficial effects of environmental information disclosure on green innovation of companies. Finally, there are significant property and regional differences in the impact of environmental information disclosure on green innovation of companies. The positive effect of environmental information disclosure on green innovation is more pronounced for state-owned enterprises and heavily polluting enterprises located in the central and western regions.

The potential limitations of this study may lie in the use of empirical data from A-share listed companies in China, and variations in data, variable assignment, analytical methods, and other factors could potentially constrain the research findings.

Submission ID: 158

Exploring Sustainable Transformation Strategies and Barriers in Taiwan's AEC Industry

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Abstract

The architecture, engineering, and construction (AEC) industry in Taiwan is at a pivotal juncture where the adoption of sustainable practices is not just an ethical imperative but also a strategic necessity. This abstract delineates the multifaceted approach toward sustainability management and leadership within the sector, emphasizing the critical role of organizational culture in fostering a conducive environment for sustainability initiatives. It is posited that the integration of Corporate Social Responsibility (CSR) within business operations is paramount to achieving long-term resilience and sustainability. The experiences and developments in sustainability management reveal a complex interplay of strategies, barriers, and actors that shape the trajectory of the industry's sustainable transformation. Furthermore, the discourse extends to strategic sustainability management as a driver for sustainable innovations, which are integral to redefining the value proposition of businesses in the AEC industry. Sustainable business models and entrepreneurship are highlighted as essential components that underpin the industry's ability to adapt and thrive in a rapidly evolving economic and environmental landscape. This abstract synthesizes the collective insights into a coherent narrative that underscores the exigencies and opportunities of sustainability in Taiwan's AEC industry.

***Keywords**: Corporate Social Responsibility (CSR), Sustainable Transformation Strategies, Sustainability Management, ESG*

This abstract directly aligns with the conference's focus on Corporate Sustainability and Corporate Social Responsibility by examining how sustainable practices can be integrated into the AEC industry's operations. It contributes to the discourse on sustainability management, leadership, organizational culture, and sustainable business models—key themes of interest for the conference. Furthermore, this research connects with several Sustainable Development Goals (SDGs), particularly:

- SDG 9 (Industry, Innovation, and Infrastructure): By exploring sustainable innovations and business models within the AEC industry, this study contributes to building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation.
- SDG 11 (Sustainable Cities and Communities): The findings have implications for making cities and human settlements inclusive, safe, resilient, and sustainable through sustainable construction practices.
- SDG 12 (Responsible Consumption and Production): The research addresses how the AEC industry can adopt sustainable practices to ensure sustainable consumption and production patterns.

By examining the barriers to and strategies for sustainable transformation in Taiwan's AEC industry, the abstract offers insight that are crucial for rescuing the SDGs 2030 for Sustainable Livelihood, linking directly to the conference's overarching theme.

Posters

Submission ID: 26

Reportings of Sustainable Mining Activities and Possibilities for Financial Support from EU Fund

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Abstract

In 2023, the European Commission adopted the European Sustainability Reporting Standards (ESRS). Therefore, many reports, publications, and policies underlined the need to improve the management and transparency of their environmental and social impacts to meet the expectations of interested stakeholders, notably communities affected by mining operations and investors. Moreover, the EU Corporate Sustainability Reporting Directive (CSRD) will require more in-depth sustainability and environmental, social, and governance (ESG) reporting by large companies in 2024. European Sustainability Reporting Standards (ESRS) will lay out the disclosure obligations of companies including mining, processing, and recycling. The mining industry is one of those facing the most difficult challenges in the context of transformation resulting from spreading the idea of sustainable development. It is impossible to demand that companies engaged in the extraction of raw materials, which are so important from the point of view of many, sectors, suddenly cease their activities or conduct them in a way that deprives them of profits. However, they can introduce changes to your production processes, making them more environmentally friendly, undertake various pro-environmental initiatives, and take into account the welfare and needs of local communities in many ways. Awareness of the need to take into account the assumptions of sustainable development in business has increased over the last two decades around the world, also among companies mining. Observing the change in attitudes among enterprises, it should be recognized that they are becoming the activities of the mining sectors will not suddenly become completely environmentally neutral, but will gradually become more friendly and compensate for the negative impact of the environment. More and more aware that running a business today is not only about concentration on profit. Moreover, the mining sector began to see what sustainable development could bring benefits and become a field for creating competitive advantage. Therefore, there are more and more programs and tools supporting the financing of sustainable mining. The work aims to present and identify tools supporting sustainable mining in connection with the new non-financial reporting. EU funds are extremely important for activities aimed at sustainable mining, in particular, due to the scale of funds involved. In recent years, there has been a noticeable increase in EU funds for the side and social effects of the mining sector. As part of this program, the innovative ValorWaste project is implemented, the aim of which is the Valorization and Integration of Extractive Waste Towards the Sustainability of Raw Materials Industry.

Submission ID: 239

Impact of Cybersecurity Management on Sustainability in the Waste Management Sector with A Focus on the NIS 2 Directive: Experiences, Developments, Barriers and Actors

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Abstract

Cybersecurity management links to sustainability in several aspects such as:
- protection of waste management data: Goal 16 (Strong institutions);
- resilience of critical infrastructure: Goal 9;
- urban safety: Goal 11;
- support of life below water: Goal 14 and life on land: Goal 15, by securing systems to monitor and control illegal dumping and contributing to the protection of marine and terrestrial ecosystems from pollution;
- using resources more efficiently - Goal 12.

The new NIS2 Directive on measures for a high common level of cybersecurity within the European Union, which EU countries must implement by 17 October 2024, confirms the recognition that the waste management sector is important and must be protected. It was pointed out that in cities, public services are increasingly connecting to digital networks to improve waste disposal. These digital utilities are vulnerable to cyberattacks. As part of their national cybersecurity strategies, Member States should develop policies that consider the development of such networks and their potential impact on society. As a result of this, waste management companies will also need to be more concerned with sustainability, in line with the SDGs Goals. Waste managers, according to the NIS2 directive, must ensure the security of the information systems used in their operations, put in place appropriate technical, operational and organizational measures, and their employees are required to undergo regular training.

The purpose of this article is to analyze the barriers and challenges in waste management companies in implementing cybersecurity management solutions. This is a very specific sector that is only at the stage of digitization, especially in municipal companies. From the interviews conducted with managers of these companies, it appears that there are several challenges that they need to address to ensure sustainability through the implementation of the NIS2 Directive. Some of these barriers are:
- the recently introduced automation of waste and transport information reporting - companies are not fully familiar with this, they already have to implement new regulations;
- access of too many external actors to manage the system;
- outdated machinery that doesn't meet safety requirements (mainly in municipal companies);
- fear of too high costs of implementing changes (cybersecurity investments are overlooked by companies as an unnecessary cost);
- legal documentation doesn't reflect actual problems;
- very low employee awareness related to cybersecurity.

The research shows that the need to implement NIS Directive 2 solutions will mean that companies will need to invest in new solutions that will need to enable rapid incident reporting and due care of the digitized infrastructure. They will also have to train their employees to raise their awareness of risks. Consequently, this will contribute to the development of cybersecurity as such in companies and, as a result, will fundamentally affect sustainability in the form of reducing waste, supporting communities, protecting data, protecting ecosystems or increasing the resilience of critical infrastructure.

5b. Design for Sustainability

Abstracts

Submission ID: 41

Revitalizing Craftsmanship in the Digital Age: A Study on Skill Enhancement and Sustainable Development of Indian Crafts in the North-East

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Abstract

The definition and contextualisation of crafts emphasise the characteristic human skill, aesthetic, and cultural values imbued in crafts, setting them apart from mechanically produced goods. It is the second largest employment generator and has a notable impact on exports, with significant contributions to the Indian economy. Despite the global demand for handicraft products, the influx of manpower is an issue. The transition to mass-produced goods, globalisation, and lack of modern market acumen among artisans has led to a decline in traditional craft practice and its transmission across generations. We focused our research on North-east of India which is located in the foothills of the Himalayas and is home to more than 50% of Indian weavers. With modernization, it has been observed that skills in crafts, traditionally passed down from one generation to the next, are experiencing a decline. This situation underscores the necessity for a structured upgrade in skills and knowledge within the handicraft sector. Various initiatives implemented under the National Handicraft Development Program (NHDP) are designed to promote, preserve, and enhance the craft sector. These initiatives focus on providing marketing support, skill development, infrastructure enhancement, and technological assistance.

This study was designed to investigate the underlying needs for skill enhancement among artisans, aiming for the sustainable development of crafts in India. Utilizing a mixed-methods approach, we conducted a thorough review of existing academic literature, policy documents, and reports focused on the sustainability of crafts, artisanal skills, and pertinent government initiatives within India. Following this, we analysed key policies and programs enacted by the Government of India that pertain to craft development, skill training, and the promotion of livelihoods. Subsequently, we carried out a field study, during which we engaged in qualitative interviews with trainees, trainers, and administrative personnel. This comprehensive approach enabled us to acquire insights into the current state of craft training and identify contemporary learning needs essential for the sustainable development of Indian crafts. While numerous government schemes and policies prioritize entrepreneurship and skill building within the crafts sector, our findings reveal that the existing craft training programs lay a strong emphasis on preserving traditional methods and cultural significance and impart only a robust focus on practical skill acquisition through hands-on experiences. There exists a notable disconnect in the training programs when it comes to imparting knowledge of modern market dynamics, consumer engagement, and the adoption of new technologies that could enhance craft marketability and sustainability. Additionally, the study identifies significant gaps in design skills, new product development, marketing strategies, and digital literacy within these programs. Despite the use of social media and web browsing for exposure, digital tools are not fully integrated into educational frameworks, limiting artisans' market reach in a digital age.

The field research amongst the different kinds of craftspeople shows that we can classify the craftspeople broadly as traditionalists or potential modernists, and Artisan Associates or Artisan Entrepreneurs. Concluding, this study offers a broad vision on how to effectively train craftspeople, thereby contributing to the achievement of Sustainable Development Goal (SDG) 4.4, which focuses on substantially increasing the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship.

Submission ID: 45

Empowering Artisanal Entrepreneurs: A Gamified Approach to Inventory Management Education

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Abstract

Most of the crafts entrepreneurs in India are not well educated. 22.5% of the handloom artisans haven't received any form of education whereas only 10.9% have above high school education. However, in order for the artisans to manage their business, they face lot of challenges. Learning management skills to better manage their business is a challenge because of the jargons in place. Also, the management schools teach way more in detail than what is necessary for the artisans in the cottage industry. The unavailability of accessible educational resources compounds this struggle, limiting the potential for growth and hindering the realization of entrepreneurial dreams. Inspired by the Antaran, a Tata Trust initiative, during my field studies, which empowers artisans through entrepreneurship programs, this project identified the lack of accessible educational resources on inventory management for artisans. Equipping artisans with the knowledge and skills to manage inventory effectively is expected to lead to a confluence of positive outcomes. Effective inventory management empowers artisans to optimize production and minimize waste, leading to increased profitability and financial independence, ultimately contributing to their self-sufficiency. So, in order to meet their cognitive and small-scale business requirements and field research data collected, we designed a simplified, gamified, yet knowledge rich way of teaching them inventory management with better knowledge retention compared to traditional methods, while simultaneously addressing the issue of educational limitations.

"Loom Inv," a board game simulating market demands and trends, was developed. Engaging four players, the game mirrors real-life scenarios by incorporating customer orders, raw materials, and currency as well as important entities like player shops and bank. Strategically designed game modifiers, like 'special events', also encourage the players to explore various possibilities to reach the optimum result, thus developing a sense of excitement. This enhanced understanding translates to improved decision-making in real-world scenarios. By participating in "Loom Inv" together, artisans foster a supportive community where they can share their knowledge and experiences, contributing to collective growth and empowerment within the artisan community. This project aligns with SDGs 4.4, 4.5, 4.7, and 4.c by providing quality education in the form of the "Loom Inv" curriculum, promoting lifelong learning opportunities through engaging game-based learning, fostering entrepreneurial skills by equipping artisans with inventory management knowledge, and promoting global citizenship within the artisan community by encouraging knowledge sharing and collaboration. "Loom Inv" offers a promising solution to bridge the knowledge gap for handloom artisans, empowering them to thrive in the dynamic marketplace. By leveraging gamification and aligning with SDGs, this intervention contributes to sustainable and inclusive economic development within the artisan community.

This research was conducted in the foothills of the Himalayas, aiming to create artisan entrepreneurs with the knowledge to efficiently management their inventory so as to reduce wastage of precious raw materials that are indigenous to the local environment, aims to foster a community of artisans who respect and nurture the nature for the resources it provides.

Submission ID: 46

Balance: A Gamified Toolkit for Sustainability-Oriented Design Thinking

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Abstract

Integrating Design for sustainability (DfS) strategies into the innovation process is challenging and presents a complex learning curve. Tools like the Cambridge sustainable design strategy cards, sustainable design toolkit by shift, and ICS toolkit have been designed to guide the ideation process. These tools are made to improve and guide product development toward environmentally responsible solutions. However, mastering the application of the tools can be challenging, especially for individuals or teams lacking prior experience in sustainability-focused ideation frameworks or the ideation part of the design process. Despite the SDO toolkit's attempt at the gap, the precautionary approach hinders creativity amongst the designers. Additionally, at the PSS level employing DfS strategies becomes a complex and wicked design problem for design students, demanding cross-disciplinary and trans-disciplinary knowledge. A significant difference has been observed between student (novice) designers and expert designers in defining the wicked design problem. The difference arises because of higher information needs, assistance in problem structuring, and presentation along with process selection. Students, therefore, need pedagogy that can aid them in perceiving the relevance of various factors involved in locating interconnections.

Taking inspiration from the prior research presenting creative DfS pedagogy, this paper addresses the issue by introducing a card-based team game called 'Balance', designed to teach sustainable design strategies based on the SDO toolkit. The game uses the SDO toolkit's framework and uses its content to design an engaging game. This enables novice designers to consider sustainability as a criterion within the context of design. Players throughout the game collaborate to apply sustainable design strategies to identify appropriate solutions to design challenges and then compete to analyse the final proposed solution to obtain the final score. This paper describes the game's design, development, and evaluation, and discusses its potential to broaden accessibility to sustainable design principles.

The game caters to both educational settings by engaging students in simulated design challenges that apply sustainability principles, and professional settings within design firms by fostering collaborative exploration and integration of sustainable solutions through a holistic approach. Thus, targeting multiple sustainability development goals: 9 for sustainable innovation, 11 for creating sustainable solutions, 12 responsible consumption and production, 13 to mitigate climate actions, 14 help us in pollution reduction, 15 on sustainable materials, land use, and reducing deforestation, and 17 helps in collaboration to achieve sustainable development and hence also link to the theme of the conference. This intervention aims to bridge the gap between existing sustainable design tools and user-friendly learning methods, potentially broadening accessibility and promoting sustainable design practices.

Submission ID: 50

Product Innovations based on Water Hyacinth for a Cleaner and Greener Planet

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Abstract

Microplastic fibers from sources such as synthetic clothing can be harmful because they have a negative impact on marine life. According to the IUCN report, the majority of primary microplastics in the ocean come from the process of washing synthetic textiles, which then end up in marine life and enter the food chain and ecosystem. Not only synthetic materials but sometimes even natural entities can be responsible for having negative impact on the ecosystem of water bodies. Eichhornia crassipes Mart. (Pontederiaceae) also known as Water hyacinth, introduced in India during British colonial rule, is a free-floating aquatic plant that originated in the Amazon Basin, then spread to other parts of the world and has been considered as global waste. Its uncontrolled rapid growth causes many problems in water bodies, such as water logging, reduction in oxygen and nutrition, loss of aquatic life, and increase in mosquito breeding. However, now the dried water hyacinth stems are utilized as raw material to create a wide range of innovative products in various parts of the world as it is easily available and free of cost. A sizable population of Northeast India relies on handicrafts for both employment and income. Rural craftsmen have benefited extensively from several initiatives taken by NEDFi, NEC, and ASRLM to promote water hyacinth (*panimeteka in Assamese*) based handicrafts.

This study highlights the information that focuses on the problem and existing solutions related to water hyacinth. It also demonstrates the scope of water hyacinth application in the textile sector, as an abundance of fiber is found in its stem, which makes it a promising plant for the textile industry. The process of making organic water hyacinth clothing includes extraction of fiber from plant stems through the mechanical and retting methods, then converting fiber into yarn by spinning method, and finally, yarn to fabric by using a handloom.

Northeast India is home to over half of the nations weavers, making it an ideal spot to implement water hyacinth in the handloom sector. The challenges that water hyacinth is expected to meet when making a sustainable substitute for natural fiber are also covered in this research. The study constitutes a conceptual model for sustainable water hyacinth design in the handloom sector. It creates a roadmap that illustrates how to promote the rural economy and transform a problem into a solution. Along with this, it also contributes to several Sustainable Development Goals created by the United Nations. By utilizing water hyacinth sustainably, it supports, Clean water and sanitation (SDG + Target: 6.6); Responsible consumption and production (SDG + Target: 12.2); and life below water (SDG + Target: 14.1). In addition to cleaning up waterways, water hyacinth offers an alternative to synthetic fiber and serves as an excellent waste management example. The current data-driven analysis will address the state-of-the-art in the field of utilization of water hyacinth as a potential raw material in innovative product design and development.

Submission ID: 108

Reimagining Design for Sustainability: Biophilic Design as a Framework for Documenting Human-Nature Transitions in Vernacular Dwellings

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Abstract

Ancient civilizations evolved in coexistence with nature. Throughout history, humans have attempted to understand their place in and relationship with nature through popular wisdom, philosophy, and practices (Vatsyayan & Baidyanath 1995). However, modern technologies today promote the notion that humans can transcend and dominate nature, resulting in an era of rapid and profound unsustainable transformations. The disconnect between humans and nature has been identified as the primary cause of current environmental crises, and reconnecting humans with nature is a proposed approach for tackling current ecological and sustainability challenges (Ives *et al.* 2018). This context also resonates with the United Nations Sustainable Development Goals (SDGs), notably SDG11+Target: 11.4 and SDG12+Target: 12.8. Biophilic design is an innovative, sustainable design concept that aims to reconnect people with nature by incorporating and retaining natural characteristics and experiences in the built environment. Although presented as a modern paradigm, biophilic design has been the way of architectural design throughout the majority of human history (Kellert *et al.* 2013). The diverse traditional architecture of rural India, shaped by regular human exposure to and engagement with nature, perceives dwellings as living entity that respond to their inhabitants and environment, exhibiting a distinct biophilic principle. Vernacular dwellings, as a community-designed traditional architectural form, presents a fundamental connection of human with nature. These vernacular architectural practices are transforming today due to modernization. Within this larger context of transition, the connection of biophilic design and vernacular architecture in India is yet to be investigated and this research attempts to fill this gap. It investigates how analysing transitions of vernacular architecture using a biophilic lens reveals significant changes in human relationship with nature. There are three models of Biophilic Design proposed in the literature: Biophilic Elements (Kellert *et al.* 2013), Biophilic Patterns (Browning *et al.* 2014) and Biophilic Experiences (Kellert 2018). This research contextualizes the biophilic experiences model with transitions in vernacular architecture, developing and presenting it as a tool for documenting transformations and understanding sustainability in the human-nature relationship within vernacular dwellings. This framework is further evaluated through a pilot case study of a vernacular dwelling in the semi-arid region of Bhal, Gujarat, India. The context of Bhal is chosen for its extreme hot and dry climatic conditions, as well as its geological formation data, which indicates it emerged from the sea as a result of sedimentation caused by eustatic sea-level changes, maybe aided by tectonic movements. Because of its oceanic origins, this region's culture and traditional architectural practices are a response to the unique natural flat landscape at sea level, irregular temperatures, and salty soil conditions. The findings suggest that biophilic model helps in understanding vernacular architectural transitions and taps into wisdom gained from long-standing human connection with nature, providing a new framework for observing transitions in the human-nature-architecture relationship. This research enables sustainability practitioners to move beyond the objective of low environmental impact in sustainability design by establishing biophilic design as traditional wisdom for understanding and reviving long-term human-nature relationships in architecture for timeless sustainability.

Keywords: *Sustainability Design, Biophilic Design, Vernacular Architecture, Human-Nature Transitions, SDGs*

Submission ID: 151

Investigation into the Impact of Featured Park Pavement Design Materials on Microclimate

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Abstract

This study is devoted to unveiling the microclimatic characteristics of featured parks in Yongkang District, Tainan City, Taiwan. Through detailed monitoring of four distinctively styled featured parks, the aim is to deeply explore the unique microclimate phenomena of these parks situated in a hot and humid climate zone. These parks not only exhibit local cultural characteristics through their playground facilities but also display a rich diversity in design, from the densely shaded Kai-Der Park and Shang-her Park to the innovatively designed Ding-Mea Featured Park and Reading Forest Park, each with its unique features. To accurately capture microclimate data, the monitoring equipment in this study was positioned 80 centimeters above the ground, a setup intended to closely match the heart height of the parks' main users—children. The monitoring period was from August to November 2023, with an average of one survey conducted per park per month, totaling 742 questionnaires from both adults and children over 30 actual measurement days. Besides choosing weekends for surveys, weekday survey times were aligned with periods of higher park usage, from 3 pm to 6 pm.

The focus of this study includes: 1. the difference between the microclimate of the featured parks and the information provided by surrounding weather stations. Through detailed comparative analysis, we not only expanded our understanding of park microclimatic characteristics but also provided the public with practical information for estimating the actual microclimate conditions of parks (such as differences in temperature, humidity, and wind speed) when consulting weather station information. 2. Further exploration into the relationship between different park features and temperature changes, including whether ground surface temperatures vary with different pavement materials, providing valuable reference information for park design. 3. The conduct of visitor satisfaction surveys, collecting feedback on the public's park usage experience to provide directional suggestions for future park design improvements. These survey results not only point the way for the future design of featured parks but also help the public understand the differences between weather station information and actual microclimates, enhancing public awareness and understanding of microclimate information.

Full Papers

Submission ID: 16

Circular and Sustainable Product Design. Rethinking the Modularity as a Strategy to Increase the Durability of Industrial Products

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Abstract

In recent years, the industrial production system has become challenged by environmental concerns and moving towards sustainable models. In this scenario, the Circular Economy (CE) represents a virtuous, closed-loop production model capable of optimising the environmental impact of goods by reusing outputs in technical and biological cycles and extending the life of products as far as possible. CE focuses on the design phase and the concept of 'modularity', applied through Design for Modularity (DfM) strategies, is consolidated as a key action to reduce environmental impact and improve product durability. Modularity makes it possible to prolong the use phase of the products by means of repairs, upgrades and remanufacturing. Several studies confirm the importance of DfM in design, both to develop more sustainable and durable products and to help manufacturing companies move towards circular and sustainable models. Through the analysis of case studies of products designed with a DfM approach and in line with SDG 12 and UN Target 12.5, the article aims to examine the importance of modularity as a key strategy to enhance the circularity and sustainability of industrial products in the circular economy.

Introduction

In light of the recent debate on the transition to a circular economy and the crucial role of design in transforming the current economic model from linear to circular, the article aims to re-discuss the concepts of 'modularity' and 'modular design' as strategic design approaches to extend the useful life of products, making them reusable, maintainable, repairable, upgradeable, remanufacturable and ultimately recyclable (Ellen MacArthur, 2013; Charter, 2018; Pietroni *et al.*, 2024). The role of design in the sustainability of industrial products and, more generally, in society was recognised in the 1970s (Papanek, 1971). A 2012 study for the European Union (EU) confirmed this, showing that 80 percent of impacts are due to decisions made at the design stage (Thackara, 2006). In this sense, modular design to extend the useful life of products is essential for a real change in traditional economic development models and for reducing the environmental damage associated with the life cycle of the products we use, consume and throw away.

The need to design for circularity through modular design strategies is reinforced by the drafting of the new Ecodesign Directive, which repeals Directive 2009/125/EC and dovetails perfectly with the EU's Extended Producer Responsibility (EPR) rules, linked to the 'polluter-pays' principle. This is a small revolution: all products placed on the market will have to meet precise ecodesign requirements: durability, reusability, reparability, efficient recycling, reduction of hazardous substances (European Parliament, 2018). Through the analysis and description of a series of case studies of products designed according to modularity criteria, the article aims to outline the current thinking that has developed within design culture on the concept of design for modularity. In recent years, the concept of modularity has

evolved from an industrial perspective of 'make to unmake', i.e. developing modular products that can be easily disassembled into their components, to 'make to remake', i.e., products that can be disassembled to extend their useful life and only as a last resort to recycle their materials. Therefore, the article aims to highlight and discuss the benefits, limitations and possible developments of modular design in the transformation of the current economic model from linear to circular, as an important design strategy for extending the life of products, increasing their intensity of use and developing new circular business models that consolidate a business culture of 'make to remake' and not just 'make to unmake' (Pietroni, Di Stefano and Galloppo, 2023).

Literature Review

The concept of modularity as a competitive strategy in industrial production was developed as early as the 1960s, when optimisation models were introduced to solve the problem of breaking down products into modules and sub-modules. This was particularly important to keep pace with the changing market, which was becoming increasingly competitive and demanding faster development times for new products. Through standardisation and modularity, it has been possible to develop platform products capable of producing different types for different sectors. In fact, a modular product allows the entire manufacturing process to be optimised through the development of standardised interfaces and the combination of modules or components, resulting in a complex but highly adaptable production model (Baldwin and Clark, 1999).

Related to the concept of the module, a well-defined unit in which components can be standard or customised to create a greater variety of configurations (Mikkola, 2006), is the issue of Design for Assembly (DfA) and, by extension, Design for Disassembly (DfD), the latter of particular interest for end-of-life management of products. Indeed, disassembly plays an important role as the first of several operations carried out on a product to prolong its life or give new life to materials. As the study by Desai and Mital (2003) shows, 80-90% of disassembly benefits are determined during the design phase. Depending on the end-of-life of the product, the most effective DfM approach must be targeted. For example, non-destructive dismantling should be preferred for maintenance and remanufacturing activities, while destructive dismantling may be more appropriate for recycling (Peeters *et al.*, 2017). Related to the issue of DfD is the question of connections and interfaces between modules. The type of fastening system, reversible or irreversible, in symbiosis with the characteristics of the product architecture, defines the quality of disassembly, i.e., the simplicity or complexity with which components and materials are separated. Although the literature pays particular attention to fasteners (Mital *et al.*, 2014; Peeters *et al.*, 2017), the design theme of making the product easily disassemblable at the end of its life is in the design of the modules and their interfaces.

As early as the 1990s, a number of eco-design scholars defined and further explored Design for Disassembly strategies to prioritise the recycling of a product's components and materials at the end of its life (Keoleian and Menerey, 1994; Manzini and Vezzoli, 1998; Bryant *et al.*, 2004; Machado and Morioka, 2021). In the same years, the problem of the complexity of the relationships between the parts and the heterogeneity of the components that make up the product architecture was simplified by an approach based on the modularity and standardisation of the parts of a product. This has made it possible, starting from a limited number of components, both to develop different configurations of finished

products (Ulrich, 1994; Miller and Pedersen, 1998; Bordignon, 2009; Yan and Feng, 2014) and to rationalise production costs and times, increase production flexibility and product customisation, reduce resource consumption and significantly improve the disassembly of components and the recycling of materials at the end of their life (Jacobs *et al.*, 2007; Umeda *et al.*, 2008).

At this stage of the sustainable design debate, the theme of modularity was developed from the industrial perspective of 'make to unmake', i.e. the design of modular products that could be easily disassembled into their components.This brought time and cost advantages in maintenance activities, if planned, and above all allowed the recovery and/or recycling of components at the end of the product's life (Halstenberg *et al.*, 2015; Bonvoisin *et al.*, 2016). The relationship between modularity and sustainability has been the subject of several studies, for example in 2004 a group of US engineers developed a method for integrating the concept of modularity throughout the product life cycle at the design stage. This was designed to optimise sustainability through a DfM approach that considered ease of recycling of materials, ease of disassembly of components and reduction of resources used in the development phase. The developed methodology is confirmed by the result of the experiment carried out on a portable vacuum cleaner, which demonstrated the effectiveness of the modular approach as a strategic lever for improving the life cycle of this type of household cleaning product (Bryant *et al.*, 2004). A few years earlier, another study looked at the same issue, focusing on product architecture to reduce environmental impact throughout the life cycle. The research was based on the assumption that the architecture of a product is crucial for the assembly of its components and, at0 the end of its life, for their separation, recycling, reuse or repair. In addition, effective design of the product architecture helps to reduce the costs associated with assembly, disassembly and maintenance, and makes it easier to plan the fate of each component from the outset (Newcomb, Bras and Rosen, 1998).

In the context of the linear economy, the Design for Modularity (DfM) approach is a design strategy that can increase economic benefits for companies while neglecting environmental issues, especially at the end of a product's life. In particular, in recent years it has been possible to identify a number of critical issues and points for reflection, such as: the nature and type of connections, which are not always compatible for disassembly; the architecture of the product, designed without taking into account a hierarchy of functions; the heterogeneity of materials, which are increasingly difficult to separate at the end of life; the complexity of module management, too many codes to manage; end-of-life management, etc. However, the development of the new DfM methodologies has enabled the development of a business and design culture of 'make to unmake', i.e., the acquisition of important know-how on material recovery and recycling processes at the end of the useful life of products. The results achieved are partly due to the innovative contribution of pilot projects for the creation of dismantling platforms, as is the case today with some white goods and car manufacturers who have recognised the importance of recovering materials from their products through active end-of-life management. This awareness has been further strengthened with the development of European programmes to support the transition to a circular economy and the development of the new EPR directives. In this new economic and social scenario, DfM plays a crucial role in drastically reducing the production of waste by designing products from a 'make to remake' perspective, which can be easily disassembled in the first instance to extend their useful life, and only as a last resort to recycle their materials.

The concept of modularity, based on the 'Make to Remake' design philosophy, is functional to the 3R strategy: Reduce-Reuse-Recycle, i.e., reduce the production of waste, reuse as many components as possible to make products more durable, repairable, maintainable, upgradeable and remanufacturable, and finally valorise materials through virtuous recycling and upcycling processes (Berg and Bakker, 2015; Sonego *et al.*, 2018). Given the recent economic outlook, which is increasingly linked to circularity issues, and in light of the Ecodesign Directive, which will expire in 2023 and will require manufacturers to adopt design strategies to increase the durability of products, the issue of modularity becomes a fundamental requirement. According to a recent study, design criteria for the development of modular and easily disassembled products should be able to transform the 'use phase' into reuse, maintenance, repair and the 'production phase' into upgrading/renewal and remanufacturing (Machado and Morioka, 2021), i.e. to promote a transition from an archetypal industrial model of 'make to unmake' to a sustainable and circular economic model of 'make to remake'.

Methodology

As anticipated, the aim of this paper is to re-examine, through the analysis of a series of case studies, the concept of 'modularity' in the circular economy scenario as a strategic design lever to extend the useful life of industrial products.

The methodology used to describe and identify the DfM strategies implemented to date in the circular economy scenario consisted of three steps: (i) literature review; (ii) analysis of three case studies of modular and durable products; (iii) development of a DfM performance summary sheet; (iv) identification of DfM strategies within the EC model and comparison of the three case studies. The first phase, described in detail in the previous section, aimed to frame the evolution of the concept of modularity within economic and industrial processes from the 1960s to the present day.The literature review identified two approaches: DfM oriented towards 'make to unmake' and DfM oriented towards 'make to remake'. The former, borrowed from industrial production optimisation processes – such as the development of standardisation and mass customisation – was functional for the production logic of large-scale industry, which supports the linear economic model, but severely limited the possibilities for a modular product to optimise even the end-of-life scenario. In fact, despite the development of DfD strategies, the only end-of-life (EoL) solution was to recover materials and send them into the recycling chain.

The second phase focused on the selection of a series of case studies, recent and virtuous from a DfM perspective, to identify the performance achieved in terms of the durability of the reuse phase and, more generally, the circularity of the business model developed from a modularly designed product. This paper discusses three DfM approaches applied to different product and technical-productive sectors: a furniture product for public spaces, described in the first case study 'Ascent' by the company Green Furniture Concept; a consumer electronics product, described in the second case study 'Framework modular laptop' by the company Framework Computer Inc; a baby carrier product, reported in the third and last case study 'Dragonfly' by the Dutch company Bugaboo International.Each example of product and company analysed was described by taking into account: the function of the product; the number of modules that characterise its architecture; the types of modules that are explicit for each performance; the physical relationships, i.e. the quality and type of connection; the materials associated with the modules; the destination after the use phase, i.e. modules intended for repair, reuse, refurbishment or recycling; the

service provided by the companies to promote the circularity and durability of the product. The third phase aimed to systematise the data collected from the case studies by producing a summary table of the DfM characteristics and performance developed. The table is a kind of qualitative measure of modularity and is divided into several parameters that aim to describe the characteristics of the DfM.

In particular, it is made explicit in the table:

i. Type of module, if it is of a structural, technological or functional nature;
ii. Type of connecting, i.e., irreversible and reversible;
iii. Tools used to dismantle the components, whether traditional or specialised;
iv. Type of service, which is dedicated to the durability of the product, return service, repair service, rental service;
v. The end-of-life scenario, i.e. the upgradeability of the modules, their remanufacturing and, finally, the recycling of the materials of which they are made.

The final phase of the research aims to describe the main macro-strategies of durability and circularity expressed in the case studies through a DfM approach based on the concept of 'make to remake'. In this phase, a representative diagram of the circular model was developed with four main strategies for durability: 'maintenance and repair' in the use phase; 'repair and reuse' in the sales and service phase; 'reuse, refurbish and remanufacture' in the production phase; 'material recycling' in the component production phase. Each case study was then compared with another, with the priority macro-strategy highlighted with a thicker line. The following section discusses the results of the methodology described.

Results and Discussion

This section describes the results of the study. It consists of the analysis of three case studies of products designed according to modularity criteria, i.e. developed according to a DfM approach based on the concept of 'make to remake', which can be disassembled to extend their useful life and, only as a last resort, to recycle their materials. The first case study relates to the public furniture sector. It is the 'Ascent' series, developed by Green Furniture Concept, a company founded in 2007 by Johan Berhin, and characterised by modular and sustainable furniture design for public spaces. The modular and sectional 'Ascent' system has been designed to maximise durability, reduce production waste and, above all, offer a high degree of flexibility and adaptability to the changing needs of public environments. The performance of the project was achieved through a DfM approach in which the modular components were subdivided according to a precise functional characterisation: structural modules; technological modules; functional modules, i.e., the parts that characterise the aesthetics, ergonomics and other performance of the product. This organisational model, together with a maintenance and replacement service for damaged parts and easy disassembly, facilitates the repair of modules, their upgrading and ultimately the extension of the life of the entire 'Ascent' furniture system. Analysing the architecture of the product, the 'Ascent' range is made up of ten modules, including structural and functional modules, which can be configured in a systematic way to create a varied and customised layout. The seat module (a) is made up of a series of single or double components that are fixed to the leg structure (b) by means of a connecting module (c) that is locked in a stable position by means of reversible connecting elements (d) that allow both the adaptation and realisation of different layouts and the integration of a series of accessory modules (Fig. 1).

The main design criteria that led to the definition of the product architecture were (i) the development of a seating module that combines various structural and functional components, such as the steel beams that support the wooden seats (both single and double), the reversible connectors, the armrest and the shelf; (ii) the development of an innovative fastening system between the different modules, characterised by a series of reversible connectors, such as a steel butterfly insert and other small parts, that allow the operator to easily and intuitively disassemble the parts for replacement, updating or maintenance.

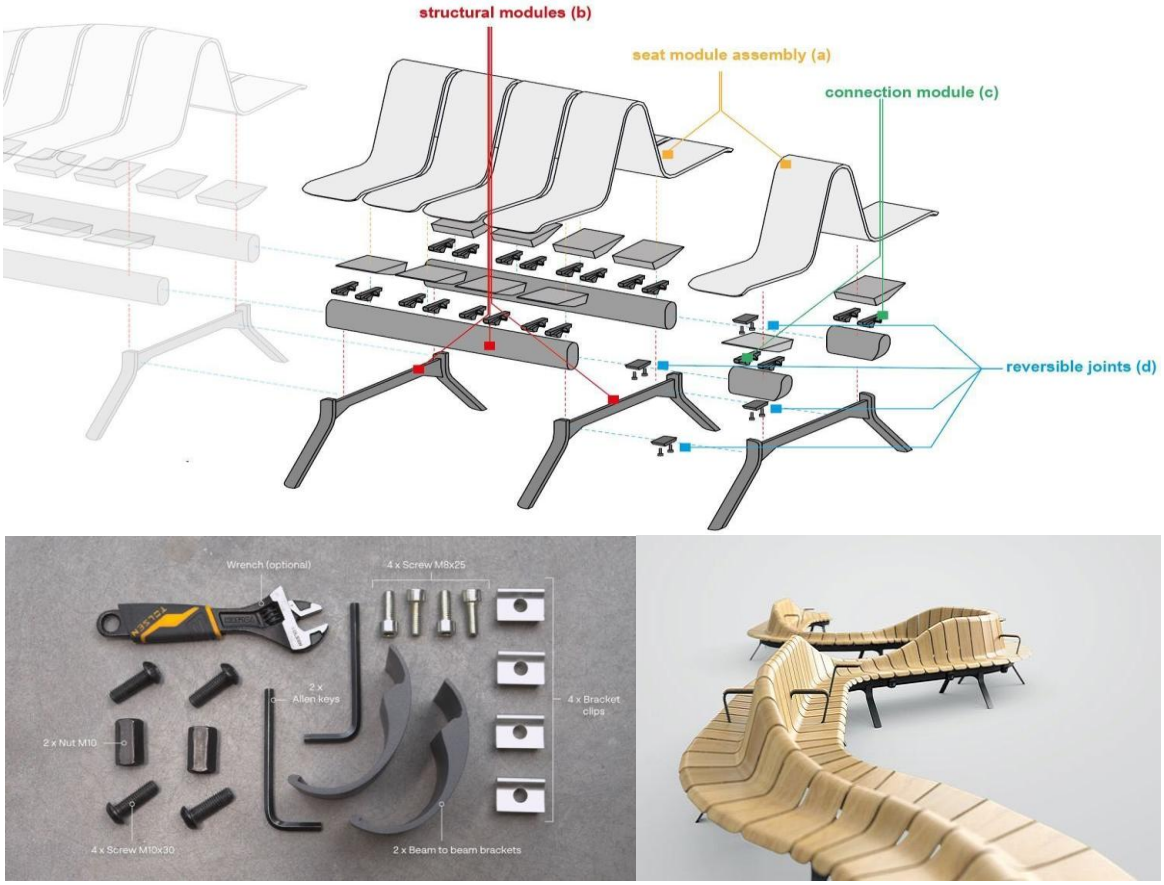

Figure 1. Architecture and module hierarchy of Green Furniture Concept's Ascent range.

The second case study relates to the consumer electronics market and aims to address the issue of obsolescence and end-of-life of these devices through the design of product/service business models that include repair, upgrade, refurbishment and remanufacturing. Among the companies that have embraced this virtuous process of circularity is Framework Computer Inc of San Francisco, USA, with its modular Framework laptop. The focus was on the product lifecycle to adapt it to different contexts of use and performance requirements. The assumption behind the project is based on an important observation: users upgrade their laptops, like most technological and electronic products, because of software obsolescence or declining processor performance. However, there is still a long way to go in terms of the ability to upgrade or replace non-technological parts and components of a notebook, as most of these

products are still severely limited by a still underdeveloped modularity and disassembly index. In this scenario, Framework developed a customisable and durable notebook solution that transformed the traditional concept of the planned obsolescence laptop through a DfM and DfD approach.

The end result is a highly modular product that allows the user to configure the computer from memory to RAM, from processor to onboard graphics, according to their specific needs. This allows users not only to customise their PC, but also to disassemble it to replace, repair or upgrade components without having to discard the entire product. The standard laptop PC is equipped with modular ports that allow users to customise the selection on the laptop on an ad hoc basis without the need for dongles or adapters. The technology modules, both internal and external, can be removed and replaced using a special key supplied with the laptop. To assist users with configuration, assembly and upgrades, Framework has developed a marketplace service for the sale of spare parts and upgrades. Each removable and replaceable part is labelled with a unique QR code that gives the user all the necessary information and instructions on how to replace it. Framework also plans to include links to buy upgrades or even used refurbished parts in its marketplace.

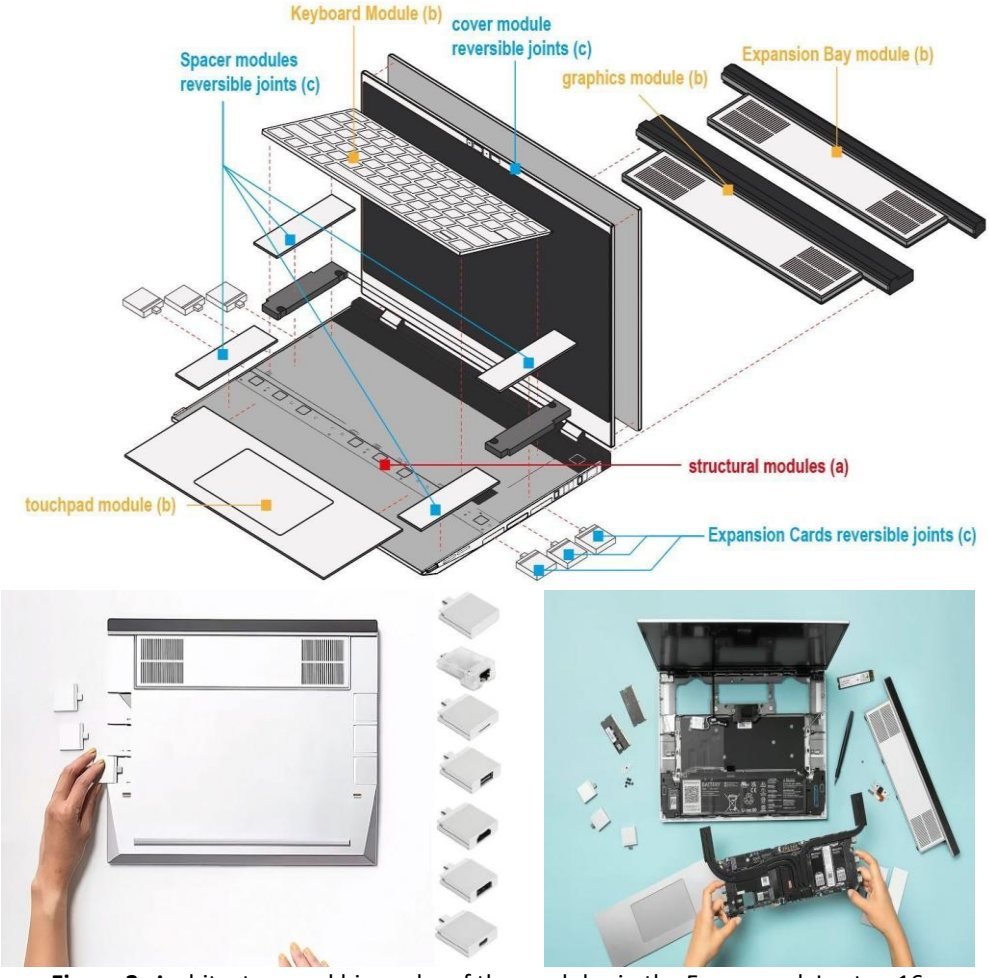

Figure 2. Architecture and hierarchy of the modules in the Framework Laptop 16

The innovation behind this product is the design of the system of connections and interfaces between the modules, which are designed as small drawers that allow the user to easily remove the individual parts by means of sliding guides. Each component of the product is a functional module of the notebook, each one interlocking with the others in a precise layout that determines the final performance of the PC. The main structural module is an aluminium case (a), designed to house both the hardware components, such as the motherboard, battery and RAM, and the modules dedicated to the interface and interaction with the notebook (b), such as the keyboard, screen, numeric keypad, laptop layout spacers, etc. In addition, module (a) can be customised via modular ports by integrating other reversible modules (c), such as USB-C, HDMI, LAN, etc., allowing the user to fully control all input and output ports (Fig. 2). Finally, the Framework phone benefits from another principle of sustainable design: the development of a takeback service for spare parts, which adds value to the user experience while extending the product life cycle.

The third case study relates to the infant mobility sector. Bugaboo is a Dutch company founded in 1994 that specialises in developing mobility solutions for children and is known for having developed the first modular pram (Fig. 3).

Figure 3. The modular pram developed by Bugaboo co-founder Max Barenbrug in 1994

In particular, through the development of the EU H2020 FP7 project, Bugaboo had the opportunity to experiment with a circular business model with the aim of creating a more sustainable, closed-loop product system, ensuring the company's profitability and maintaining high product quality (Sumter, Bakker and Balkenende, 2018). The pilot project carried out a Life Cycle Assessment (LCA), which showed that part of the environmental impact is due to the dismantling phase, which is underdeveloped because the parts are irreversibly attached to the frame. On the basis of the results of the LCA, the research team initiated a pilot project for the leasing and refurbishment of Bugaboo products called the “Bugaboo Flex Plan”. The service involves renting the prams for two consecutive cycles of use and then refurbishing them after each rental cycle. After the second rental cycle, the buggies are refurbished, certified and sold on the second-hand market (Bugaboo Refurbished). To ensure that the service has a positive impact on the company's business, Bugaboo has adopted a modular approach to many of its products, one of the most representative being the 'Dragonfly' (Fig. 4).The architecture of the 'Dragonfly' pram is made up of three

modules assembled according to a specific hierarchy: the structural module of the chassis (a); the storage module (b), which can have three versions: carrycot/passenger seat/object; the reversible modules of the front and rear wheel system (c). In addition to the basic product consisting of components (a, b, c), a number of accessory modules (d) can be attached to the main structure. These are items such as the lower storage pocket, the sunshade, the extension for carrying two children, etc. The design of the frame (a) has been conceived as a central core in which all the relevant functional modules and mobility accessories are reversibly interconnected so that they can be disassembled and replaced regardless of the state of wear or damage to the others. The types of modules and their connections allow users to create a wide range of configurations and to repair, upgrade, refurbish and remanufacture both components and the entire product. The main design criteria that led to the definition of the architecture of this product were: the realisation of a structural frame that allows the aggregation of different functional components, such as the storage modules, useful for the multiple needs or different growth phases of the child (carrycot, baby carrier, pram, etc.); the realisation of reversible connection systems that offer the user the possibility of repairing or replacing components to modify and extend the product's performance. In summary, the DfM approach to the development of the 'Dragonfly' pushchair is primarily aimed at creating a product that is configurable in terms of its performance in use, easy to maintain and upgrade over time, through the company's sales channel and maintenance support service.

Figure 4. Modular structure of the Bugaboo Dragonfly pushchair

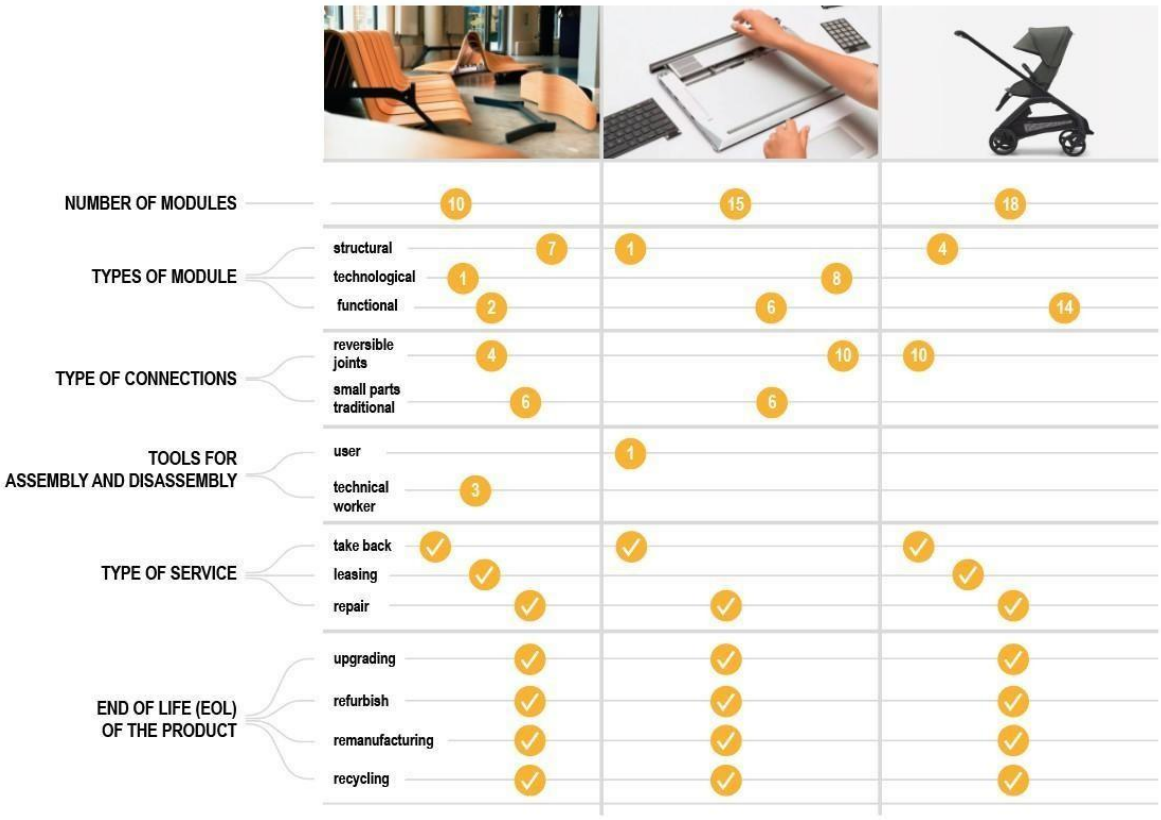

Figure 5. Case study comparison sheet.

To obtain qualitative feedback on the DfM criteria and parameters for making products more circular and durable, a summary table was created comparing the Design for Modularity features and performance developed in the three case studies (Fig. 5). The table shows the performance aspects related to the DfM, including: the function of the product and the number of modules actually available; a distinction between the types of modules for the different performances; the physical connections that the user or specialised personnel can have with the tools, if any, to facilitate the disassembly of the components and to facilitate the maintenance, repair, upgrading, re-qualification and refurbishment of the product; the associated materials; the post-use provisions and the services provided (such as pickup, rental, repair, etc.) to facilitate the circulation and longevity of each product.

The table shows that: (i) the number of modules for complex products such as electronics and mobility products is generally very high (more than ten); (ii) the types are closely correlated to the product and the context of use, but it is possible to observe the constant presence of at least one structural module; (iii) the type of irreversible connection most often used is that through small parts; (iv) the services offered by the companies are a constant factor to generate a truly durable product; (iv) the services offered by the companies are a constant determinant to generate a truly durable product; (vi) despite different commercial sectors, all three companies offer at least one take-back and repair service; (vii) the DfM strategies adopted allow to optimise the different EoL scenarios for all three products analysed. The DfM

strategies explained in the case studies were compared in terms of the circularity performance achieved by the three companies, highlighting the main material and resource flows optimised through four different scenarios, namely: maintain & repair; repair & reuse; reuse, refurbish & remanufacture; recycle.As shown in the figure (Fig. 6), in the first and third case studies priority is given to maintenance and repair for use, while in the second case priority is given to maintenance and reuse through reconditioning and remanufacturing for the production of new products.

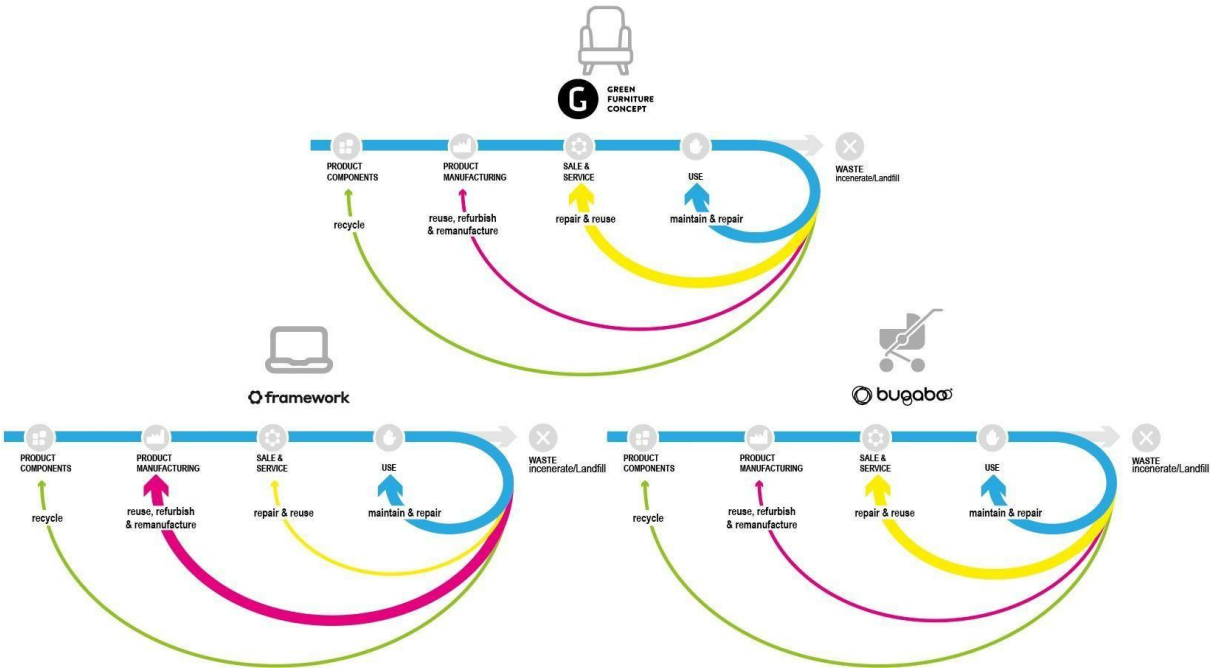

Figure 6. Identification and comparison of the most important strategies for circularity by means of a DfM approach

Conclusion

In conclusion, the analysis of the case studies highlights the strategic importance of Design for Modularity as a tool to improve the practical implementation of circularity in companies. Many companies are now adopting such new approaches to design for modularity to improve the circularity and longevity of their products, including through the development of services.

The analysis of the three case studies made it possible to identify the different approaches to circularity pursued by the DfM strategies and also to highlight the importance of modularity in the industrialisation process of complex products in order to achieve high benefits, both in terms of production efficiency and environmental sustainability. In fact, as the case studies show, faulty modules can be easily identified, separated and replaced with new or refurbished ones, extending product and material life and eliminating waste. In recent years, with the escalation of environmental issues, this type of approach has played a crucial role in industrial design and has become a fundamental prerequisite for increasing the circularity of products and their materials. The traditional concept of modularity developed in the 1990s, in which products were designed with an eye to 'unmaking', i.e., dismantling for the sole purpose of recycling materials, has now been superseded. Today, we can say that modular design is not only a prerequisite,

but a strategic business lever aimed at the culture of 'making to remake' and 'making to unmake', of 'reducing' and 'reusing' first, and then 'recycling'. Through the analysis of the three products, the change in the concept of DfM and DfD emerges significantly, marking the shift in design culture from 'disassembling' to 'remaking', i.e. modularity applied as a design practice that can be declined and is effective in extending the useful life of products belonging to different product sectors: from those for personal mobility to those for urban furniture, from electronic devices to those for fashion, etc.

As described in the case studies, for the business model to be truly circular, it is crucial that companies not only implement the new DfM design criteria and make most of their components reusable and remanufacturable, but also provide a range of maintenance, repair, upgrade and remanufacturing services. The development and delivery of these services is a sine qua non for a radical shift to a more circular business model, and the lack of them is the main barrier for companies. Despite the difficulties, in recent years many companies in the manufacturing sector have begun to adopt design practices aimed at improving the environmental performance of their products and moving away from the 'take-makewaste' model. This change is encouraged both by the introduction of new regulations, such as the 'Ecodesign for Sustainable Products Regulation' (ESPR) 2024/1781 (European Commission, 2024), and by waste management practices (defined by Extended Producer Responsibility - EPR), which aim to design modular products that are truly circular, i.e. durable and ultimately more recyclable.

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Materials Research in Design: A Bibliometric Analysis

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Abstract

Advancements in materials science have supported technologies addressing sustainability, but their implementation often harms society and the environment. Recently, Materials Research in Design (MRID) has emerged, with designers leading material research from a cultural and humanistic perspective, differing from traditional material development. This study uses bibliometric analysis and CiteSpace to evaluate MRID literature from 20032023 in the Web of Science. The search strategy included TI= ("material design" OR "design material" OR "material" OR "material creative"), covering SSCI, SCI-Expanded, A&HCI, CPCI-S, and ESCI indexes. After deduplication and expert review, 212 pieces of literature were analyzed. Results indicate that MRID is in its infancy, suffering from limited resources and collaboration. Research trends show strong sustainable development influence and interdisciplinary characteristics, with design science increasingly involved in material development. Designers are predicted to continue exploring the beauty and cultural significance of waste materials for sustainable design. The significance of this research lies in highlighting the potential for design-led materials research to drive innovative, sustainable practices and inform future interdisciplinary collaborations in material science and design.

Introduction

Materials science and engineering have long dominated materials research (Schoenung *et al.*, 2023). Many advances in materials science have provided the necessary foundation for developing technologies that achieve sustainable development goals. However, the implementation of these technologies and the application of materials often result in undesirable impacts on human society and the environment. In recent years, a new phenomenon has emerged in the design field, known as materials design, where designers lead material research. Unlike scientists, designers often aim to address sustainability issues. In other words, the concept of materials design is based on the principles of sustainable development, approaching the development and application of new materials from cultural and experiential humanistic perspectives. This phenomenon differs significantly from traditional material development in the field of materials science, warranting comprehensive examination to analyze its causes, current status, and future trends.

Literature Review

MRID is increasingly integrated with sustainable development, highlighting its role in addressing environmental and societal impacts. Material Driven Design (MDD) by Karana *et al.* (2015) emphasizes combining material properties and experiential qualities to promote sustainability and user-centered designs. This approach encourages designers to consider the environmental impact and sensory experiences of materials, fostering deeper product-user connections. Zhou (2021) underscores the importance of sustainability in design education, advocating for hands-on experience with sustainable materials to enhance innovative and informed decision-making. Pedgley *et al.* (2016) focus on materials experience, emphasizing sensory and emotional responses to materials, which can significantly influence sustainable design practices. Understanding these aspects aligns with sustainable development principles, prioritizing long-term usability and minimal environmental impact. Barati and Karana (2019) explore

affordances in material design, recognizing that sustainable affordances can lead to intuitive, user-friendly, and environmentally responsible designs. Despite progress, existing research lacks a comprehensive overview of MRID, particularly in the context of sustainability, resulting in a fragmented understanding of the field's development. Fundamental research on the current state and future directions of MRID is needed. In summary, the integration of MRID and sustainability indicates a shift towards addressing environmental and social challenges, positively impacting sustainable development goals. However, systematic reviews are needed to fully understand the field's development. By focusing on sustainability, material properties, and user experience, researchers and practitioners can advance MRID and contribute to a sustainable future.

Bibliometric analysis has increasingly been recognized as an effective method to explore a research field's development and overarching trends. Over time, bibliometrics has been extended to almost all disciplines (Aria *et al.*, 2017). Bibliometric techniques can visualize the knowledge network and track how scientific ideas evolve, offering insights that are difficult to capture through conventional review methods (van Eck *et al.*, 2014). This approach offers a systematic, transparent, and reproducible review process than traditional literature reviews (Broadus, 1987, Diodato, 2013, Pritchard, 1969). However, the exclusive reliance on bibliometric analysis has its limitations and can lead to homogenized and potentially biased conclusions. This issue is particularly pronounced in fields like materials design, where a lack of a clear and universally accepted definition complicates the ability to accurately track and analyze relevant publications. Without a clear definition, studies may inadvertently include or exclude relevant works, leading to skewed data and interpretations. Moreover, bibliometric analyses typically focus on measurable metrics such as citations and publication counts, which might not fully reflect the true impact or innovative nature of research, especially in rapidly evolving fields (Bornmann *et al.*, 2014). To mitigate these risks, scholars suggest complementing bibliometric analysis with qualitative methods such as systematic literature reviews, expert interviews, and case studies (Wang *et al.*, 2022). This mixed-methods approach can provide a deeper understanding of the context and qualitative nuances that bibliometric methods might overlook.

Addressing these issues, this study aims to systematically review the current status and trends of materials design research globally through a combination of bibliometric analysis and content analysis, mutually corroborating the findings. The study will visually present the knowledge structure using knowledge mapping, providing effective references for future theoretical and practical developments in MRID.

Methodology

Research Methods

Bibliometric research is a study that utilizes quantitative analysis methods to analyze literature using metric concepts and methods (Merigó *et al.*, 2015). It became an independent discipline in 1969 (Pritchard, 1969), initially used in library and information science, and later adopted by other disciplines, including design, to analyze the development status and trends of a specific field. This study employs two mainstream bibliometric visualization software, CiteSpace 6.2.R4 and VOSviewer 1.6.19, to perform co-occurrence and evolution analysis of materials design research literature. The analysis focuses on external data (such as the number of annual publications, core authors, core countries, and institutions) and keywords to reveal the research status and trends in this field. The study also explores how the concept of sustainable development influences materials design research.

Data Sources

To ensure the scientific rigor, objectivity, and reproducibility of this research, the Web of Science Core Collection (WOSCC) was selected as the data source. The first relevant paper in the WOSCC was published in 2003 (Doordan, 2003), so the search timeframe was defined as January 1, 2003, to January 1, 2024.

As previously mentioned, it is challenging to unify the various definitions of materials research in design under a single comprehensive term. Therefore, this study employs a combined approach of broad concept retrieval and manual screening for the search strategy. After multiple attempts, the search query was determined to be “TI= ("material design" OR "design material" OR "material" OR "material creative")”. Since these keywords are frequently used in materials science and other disciplines, additional criteria were established to exclude irrelevant literature. Based on other relevant review studies, inclusion criteria were formulated, as shown in Table 1. Through screening, 201 English articles from the WOSCC met these standards. The research process is illustrated in Figure 1.

Table 1. MRID Literature Screening Criteria

Standard	Description
Document Content	1.The literature must include clear research questions, research methods, and research results; 2. The study primarily focuses on MRID. Since design studies involve interdisciplinary aspects, literature that does not clearly state the connection with MRID or has weak relevance will be excluded.
Document Quality	1.The literature should have complete information elements, including abstract, author, institution, keywords, references, etc.; literature with incomplete information elements will be excluded; 2. The literature should be peer-reviewed to ensure academic quality and reliability.
Document Type	1.Only literature written in English and from articles and proceedings papers is included; literature types such as reviews, editorial materials, book reviews, etc., are excluded

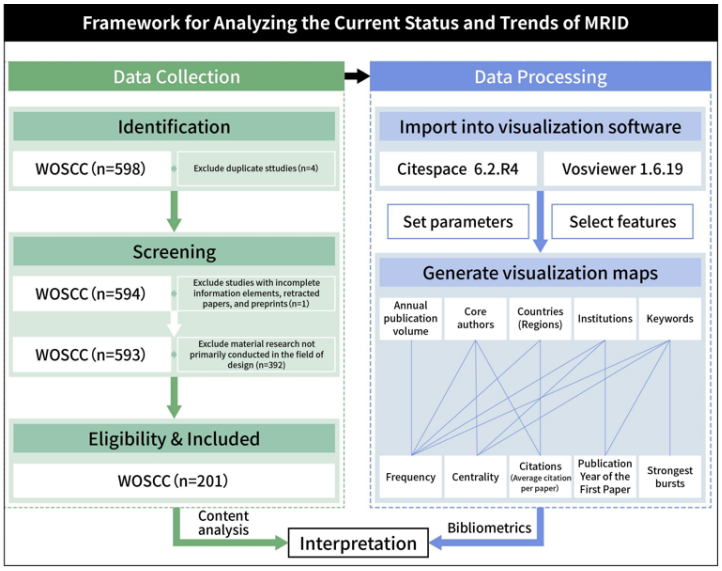

Figure 1. Flowchart of the Article Selection Process for MRID Bibliometric Mapping Analysis and Systematic Review

Results and Discussions

The 201 WOSCC articles used in this study come from 38 countries, 227 institutions, and 451 authors. These articles were published in 104 journals and cited 5818 references from 3945 journals.

Current Status of MRID Based on External Data

Annual publication volume

Changes in the annual publication volume can reflect the development trends of a research field (Wang *et al.*, 2024). According to the statistics and linear prediction of annual publication volume, as shown in Figure 2, the volume of materials design research is relatively small. The yearly publication volume has been between 10 and 20 articles in recent years, showing a slow and fluctuating growth trend.

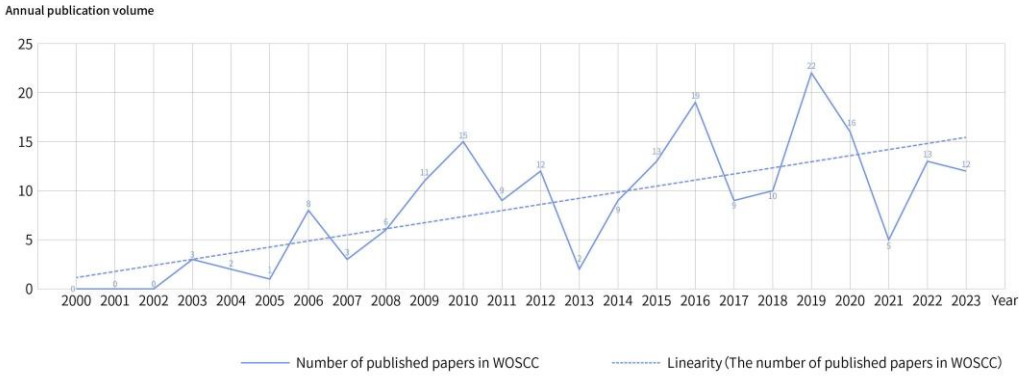

Figure 2. Distribution of Annual Publication Volume for MRID and Linear Regression Forecast

Due to the relatively small volume of research in the field, publication frequency tends to fluctuate and is mainly influenced by the progress of core authors in the field. A historical review identifies three significant fluctuation points. First, in 2002, Mike Ashby and Kara Johnson systematically focused on the humanistic value of materials from a designer's perspective for the first time (Ashby *et al.*, 2002). Designers began to consider ecological and social impacts in the material selection process, leading to a slow increase in materials design literature thereafter. Second, in 2013, Elvin Karana and colleagues invited a representative group of scholars to share their insights on materials design from the perspectives of experience, sustainability, technology, and choice, compiling these into "MATERIALS EXPERIENCE" (Karana *et al.*, 2013), which not only elevated the impact of materials design research but also further promoted sustainability as a crucial issue, despite causing a short-term decline in journal publications. Third, between 2016 and 2022, the "Emerging Material Experiences" special issue in "Materials & Design" focused on new experiences brought by "Emerging Materials" in design (Van der Velden *et al.*, 2015), social sciences (Lilley *et al.*, 2016), and materials science and engineering (Wilkes *et al.*, 2016), producing a series of high-quality research outcomes that significantly increased annual publication volume. Notably, although sustainability was not explicitly emphasized in the special issue, nearly all studies inherently considered sustainability. Since then, materials design research has formed a close association with sustainability. Additionally, due to the emphasis on conducting research with real materials, the COVID-19 pandemic also impacted publication volume after 2019.

Core authors

The representative scholars in this field are shown in Table 2, where the top four authors by publication volume have collaborated multiple times, focusing primarily on material experience (Karana *et al.*, 2015). This is closely related to the tradition of collaborative research in the West, especially after Karana and Hekkert first used the term "material experience" in 2008 (Karana *et al.*, 2008). Karana, Rognoli, and Pedgley have continuously expanded on this theme, producing a series of influential outcomes, particularly since 2015, when Material Experience became increasingly associated with sustainable design. Additionally, Karana and Rognoli co-founded the transnational research group Material Experience Lab to conduct interdisciplinary research.

Table 2. Top Authors Ranked by Number of Publications

Rank	Author	Publications	Total of Citations	Citations Per Paper
1	Elvin Karana	18	556	30.89
2	Valentina Rognoli	10	270	27
3	Owain Pedgley	8	87	10.88
4	Paul Hekkert	5	238	47.6
5	Mikael Wiberg	5	194	38.8

From the perspective of the quality of collaboration among core authors, the renowned American scholar D. J. S. Price proposed that within the same theme, half of the papers are written by a group of highly productive authors. The number of authors in this group is approximately equal to the square root of the total number of all authors involved, as shown in Equation (1).

$$_{m+1}n(x) = \sqrt{N} \quad (1)$$

Here, n(x) represents the number of authors who have written x papers, I= n_{max} is the number of papers published by the most productive author in the field, N is the total number of authors, and m is the minimum number of publications by core authors. According to Price's Law (Qiu, 2007), the minimum number of publications by core authors in a field is shown in Equation (2).

$$m = 0.749 \times \sqrt{n_{max}} \quad (2)$$

According to statistics from VOSviewer, the total number of authors in the WOSCC database is n_{max} =18. By applying Equation (2), the calculation yields m≈3.18. Authors with 3 or more publications (including 3) are designated as core authors in the field, totaling 14 authors who have collectively published 74 papers, accounting for 37% of the total publication volume. According to Price's Law, since the publication volume of core authors does not account for 50% or more of the total publication volume, it indicates that researchers in this field have not yet formed a stable collaborative group.

Countries (Regions)

The collaboration and influence of major countries (regions) and research institutions can provide direction and topics for in-depth research in a particular field (Ren *et al.*, 2023). Statistical data show that

the outcomes of materials design research come from 37 countries. As seen in Table 3, although the Netherlands is not the country with the highest number of publications, it stands out because Karana (the most cited author) and Hekkert (the author with the highest average citations per article) are both from this country, resulting in the highest overall citation and average citations per article for the Netherlands.

Table 3. Top Countries (Regions) Ranked byNnumber of Publications

Rank	Countries (Regions)	Publications	Total of Citations	Citations Per Paper
1	England	33	352	10.67
2	USA	29	557	19.21
3	Netherlands	27	696	25.78
4	China	21	212	10.6
5	Italy	17	160	9.41

Figure 3 visually demonstrates the relationship between the publication volume and collaboration intensity of different countries. Among the top five countries in terms of publication volume, all except China show a positive correlation between publication volume and collaboration intensity. It is noteworthy that although China ranks fourth in publication volume, it lacks international collaboration, having only collaborated with the United States and the United Kingdom.

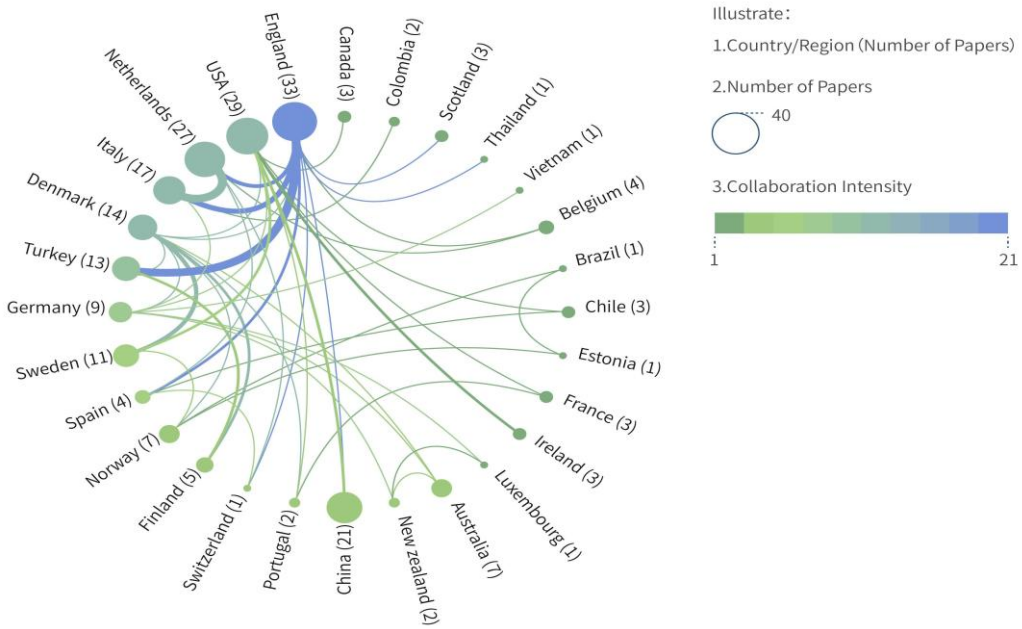

Figure 3. Relationship between Publication Volume and Collaboration Intensity for MRID across Top Countries

Institutions

Table 4 displays the top five institutions in terms of publication volume. From the perspective of institution type, universities, particularly comprehensive universities, are the primary research bodies. Collaboration among universities is usually academically oriented, focusing on theoretical research and

frontier exploration, and comprehensive universities are especially conducive to facilitating multidisciplinary cooperation. This indirectly highlights the interdisciplinary, theoretical, and cuttingedge characteristics of the field.

In CiteSpace, centrality is a key metric for analyzing influence. If centrality is greater than or equal to 0.1, it indicates that the node is a central node, important and influential in the research. Looking at the influence of institutions, the centrality of all institutions is below 0.1, indicating that there are no highly influential research institutions globally at present. Politecnico di Milano has slightly higher brokerage centrality than other institutions, with a tradition of collaborative research and only one independent study. Institutions like Delft University of Technology, although having the highest publication volume, conduct nearly half of their research independently.

Table 4. Top Institutions Ranked by Number of Publications

Rank	Institution	Publications	Betweenness Centrality	Publication Year of the First Paper
1	Delft University of Technology	25	0.00	2006
2	Polytechnic University of Milan	14	0.02	2015
3	Middle East Technical University	6	0.01	2009
4	Loughborough University	5	0.00	2012
5	Zhejiang University	5	0.01	2008

4.2. Research Hotspots in MRID Based on Keywords

Keywords play a crucial role in refining and summarizing the core content of articles. After removing keywords that are highly similar to the search terms (including "design," "material design," and "design materials"), 796 keywords were retained. In CiteSpace, the centrality and burstiness of keywords indicate the phenomena where certain keywords frequently appear within a specific period. These metrics not only show the evolution of research hotspots over time but also indicate recent research directions and may hint at future research trends. Table 5 displays the top ten keywords (including ties) ranked by frequency of occurrence.

Table 5. Top Keywords Ranked by Frequency

Keyword	Frequency	Centrality	Keyword	Frequency	Centrality
material selection	32	0.33	design education	7	0.02
product design	17	0.10	design theory	6	0.08
materials experience	12	0.14	design tools	6	0.05
industrial design	8	0.07	knowledge	5	0.14
interaction design	7	0.06	form	5	0.05
conceptual design	7	0.14	framework	5	0.18

From the perspective of centrality, six keywords have a centrality greater than or equal to 0.1, signifying well-established research hotspots with high influence. These keywords can be categorized into two groups: one includes "product design" and "concept design," which refer to design categories and stages; the other includes "material selection," "material experience," "knowledge," and "framework," which pertain to the core themes of materials research.

Table 6 shows the top ten emerging keywords, ranked from earliest to most recent burst start year. Since 2017, the keyword "knowledge" has sparked scholarly interest by representing studies that integrate design thinking into material development, and it is expected to continue attracting attention in the future. This trend aligns with Barati and Karana's findings that "upstream" collaboration between designers and material scientists (such as in material invention) is increasing (Barati *et al.*, 2019). "Materials experience" remains a research hotspot, especially in developing assessment standards and tools for evaluating the sensory properties of materials (Abella *et al.*, 2022).

Table 6. Top Keywords with the Strongest Bursts

Keyword	Year	Strength	Begin	End	2000-2023
conceptual design	2004	1.76	2004	2010	
product design	2003	3.65	2008	2010	
material selection	2003	2.66	2008	2010	
industrial design	2009	1.68	2009	2010	
interaction design	2010	1.61	2010	2014	
knowledge	2017	1.74	2017	2023	
aesthetics	2017	1.71	2017	2018	
form	2016	2.05	2019	2020	
architectural design	2019	1.64	2019	2020	
materials experience	2015	2.83	2020	2023	

Trends in MRID Based on Keyword

The use of keyword network visualization (clustering) and overlay views (temporal) generated in VOSviewer plays a crucial role in understanding the development trends of a particular field. This study analyzed 62 keywords that appeared three times or more in the WOSCC database through clustering visualization. Each cluster was set to include no fewer than seven keywords, resulting in the formation of four clusters, as shown in Figure 4. This method provides a comprehensive and systematic view of the relationships and evolution of research themes within the field of materials design.

MRID development trends

Interdisciplinary clues are increasingly prominent throughout the evolution of MRID research. Cluster 1, centered on the keyword "material selection," represents the earliest and most classical paradigm in materials design research. The field recognizes Ezio Manzini and Mike Ashby as pioneers of MRID. Manzini introduced and advocated for the concept of material autonomy, suggesting that materials themselves can be viewed as objects of design (Manzini, 1989), laying the groundwork for subsequent designer-led materials research. Ashby and others discussed materials from a "designer's" perspective, linking engineering properties, technical feasibility, and product aesthetics, thus building a platform for communication among materials scientists, engineers, and designers (Zuo, 2020). Ashby's contributions are notable for their traditional and interdisciplinary nature, subsequently expanding material selection research to include a comprehensive perspective that encompasses sensory features.

Entering the 21st century, with the advancements in digital technology and the rise of the experience economy, design shifted from focusing on "products" to "interactions," where products became mediums for communication and connection, and experience emerged as a new design object.

Consequently, the role of materials evolved from traditional functional applications to creating experiences. At this point, MRID branched into two distinct paths.

One branch, centered on the keyword "interaction design," formed Cluster 2. In this cluster, materials are considered important mediums in interaction design (Wiberg, 2016), and two opposing viewpoints emerged: one perspective views computers as design materials, discussing their role in creating new expressions and user experiences in human-computer interactions (Wiberg *et al.*, 2013); the other argues that computers cannot be perceived as standalone design materials without integration with other media, therefore they cannot independently serve as design materials (Vallgårda *et al.*, 2010). However, neither of perspective sustained a broader range of topics, and around 2018, research gradually returned to the fundamental studies of interaction design.

The other dominant cluster within MRID focuses on "materials experience," forming Cluster 3. This cluster builds on Ashby's theories (Zuo, 2010), where the concept of sustainable development became a key factor influencing the expansion of material experiences. "Materials experience" specifically refers to the experiences people gain through using product materials. Karana *et al.*, (2014) have categorized the sensorial level (such as cold, and smooth), interpretive level (such as modern, and sexy), affective level (such as surprise, and pleasure), and performative level (such as caressing, and fiddling) of materials into four dimensions of materials experience. Initially, scholars focused on understanding people's acceptance of new and alternative materials through the lens of materials experience. As the complexity of "sustainability" increased, addressing sustainability issues often required interdisciplinary collaboration. Social changes also enabled cross-disciplinary opportunities, with technological backgrounds like citizen science, distributed manufacturing, and open-source platforms facilitating the democratization of manufacturing. The formation of responsible consumption perspectives, desires for personalization, and crowdfunding environments have provided designers with opportunities to transform their relationships with materials, leading to a shift in materials experience. In 2015, materials experience inspired a series of more radical themes, such as DIY material design (Rognoli *et al.*, 2015). These themes, driven by innovation and motivated by the development of alternative materials, focus on inventing more sustainable, recyclable materials for application. Designers have shown strong interest and ability to personally engage in defining the sensory and even physicochemical properties of materials.

Designers, in their quest for autonomy in invention, have increasingly collaborated with disciplines such as materials science and engineering. This led to the emergence of Cluster 4, centered around the keyword "knowledge" and "framework," characterized by significant interdisciplinary collaboration. Scholars in this cluster have been integrating design thinking into the routine tasks of materials science and engineering, making creative contributions to materials development. For instance, Barati Bahareh and others proposed the "Materials Potential Framework," which enables designers to transcend the limitations of given materials and lead in the creation of new materials (Barati *et al.*, 2019). Similarly, Kirsi Niinimaki demonstrated how design thinking could drive technological innovation in materials through a material development project (Niinimäki, 2019), illustrating that design methodologies can significantly enhance material innovation.

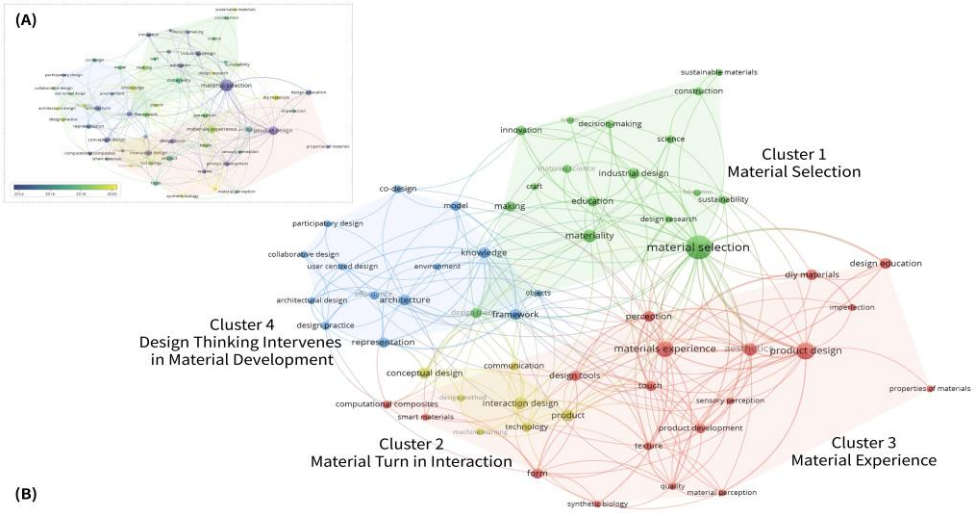

Figure 4. Analysis of Keyword Co-occurrence. (A) The Distribution of the MRID Using the Keyword by Years. (B) The Most Used Keyword in the MRID

Evolutionary path summary

The evolutionary path of MRID, as depicted in Figure 5, demonstrates a linear progression trend. Since its inception, materials design research has implicitly contained interdisciplinary clues. As it has evolved, the interdisciplinary characteristics have become increasingly prominent, evident in both the naming of clusters and the types of terms used, with little emphasis on the disciplinary attributes of research themes. Moreover, the concept of sustainable development has significantly influenced the evolution of materials design research. The emergence of sustainability concepts provided a directional focus for the loosely structured field of MRID, specifically towards materials experience.

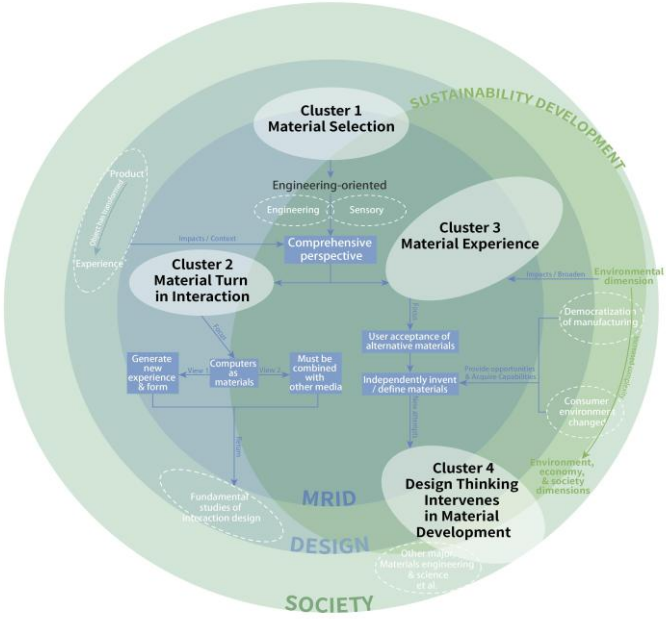

Figure 5. The Evolutionary Path of MRID

Overall, the research theme clusters have led to an expanding trend in the scope of research, with design increasingly participating in topics within the materials science domain, such as material development. This trend highlights the growing integration of design principles and methodologies into traditional materials science, driving innovation and fostering new approaches to material research and development.

Conclusion

This paper has undertaken a comprehensive bibliometric analysis of MRID from 2003 to 2023, focusing on how designers, diverging from traditional materials science approaches, are spearheading material innovation with an emphasis on sustainability and humanistic values. By evaluating 201 pieces of literature through the bibliometric tools CiteSpace and VOSviewer, the research has charted the developmental trajectory and thematic evolutions within MRID.

The following conclusions were drawn from the analysis: (1) Infancy of MRID: The characterized of the field by modest research outputs and fluctuating publication volumes. Despite the pivotal role of sustainability in driving research, MRID suffers from limited resources and collaboration, highlighting a need for more consolidated efforts in this area. (2) Interdisciplinary and Sustainable Development Focus: The research underscores a significant interdisciplinary approach integrating design sciences into material development. This shift towards sustainability is seen as not only a thematic but also a methodological reorientation in how materials are researched and developed, prioritizing environmental impacts and user-centric experiences. (3) Increasing Influence of Design in Material Science: Designers are progressively at the forefront of exploring the aesthetic and cultural significance of materials, particularly waste materials, in their creative processes. This trend is predicted to strengthen as the boundaries between design and material science continue to blur.

The significance of this study lies in its illumination of how design-led approaches in material research can lead to innovative, sustainable practices that are culturally and environmentally responsible. The interdisciplinary nature of MRID also suggests that future research could benefit from more collaborative frameworks that bring together designers, material scientists, and industry stakeholders.

However, it should be acknowledged that this study also has some limitations. First, in order to ensure data integrity, this paper excluded some databases (such as Scopus), which will inevitably miss some relevant literature; in addition, since this study focuses on reviewing the content of the literature from an overall perspective, no in-depth analysis of individual important literature was conducted. Therefore, it is recommended that future research can conduct analysis based on other important databases horizontally and conduct in-depth analysis of some high-impact literature in this field vertically, and conduct a more in-depth analysis of the current status and trends of material design research from two dimensions.

This research paves the way for further exploration into how materials can be developed and manipulated not just for functional benefits but also for their potential to enrich human and environmental well-being. Through fostering greater understanding and collaboration across disciplines, MRID can contribute to a more sustainable and aesthetically enriched future.

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Environmental and Bio-Inspired Re-Design of Sebach's Topsan Notouch 2.0 Portable Toilet: Quantitative Assessment of the Environmental Benefits Obtained from the Biomimetic Approach to Product Design

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Abstract

The article presents and discusses the conclusive and unpublished results of the doctoral research 'Biomimetic re-design of sustainable products. Increasing the environmental sustainability of products through biomimetic criteria' (Balsamo, PhD Thesis, 2023) aimed at analysing and quantifying the contribution of the bio-inspired approach in the design of sustainable industrial products. Bio-inspiration, recognised by many experts as an important innovation factor, aims to improve the environmental sustainability of products. In order to quantitatively assess the real benefits of this approach, a bio-inspired re-design of the TopSan NoTouch 2.0 portable toilet from Sebach S.p.A., a product certified with an Enviromental Product Declaration, was carried out. Initially, a product analysis was conducted to define the environmental improvement goals to be achieved through bio-inspired design criteria. Bioinspired re-design involved the implementation of diverse methodological approaches and operational tools, involving experts from other disciplines, such as biology and engineering, in order to acquire complementary technical-scientific knowledge. Through the use of the standardised Life Cycle Analysis (LCA) methodology, it was possible to quantitatively assess the environmental impacts of both the original product and its re-designed version according to bio-inspired principles. The comparison between the two products showed positive results that validate the effectiveness of the bio-inspired approach in the design of industrial products in terms of increasing environmental sustainability.

Introduction

In recent years, the growing awareness of various contemporary crises - climate, environmental, energy and others - has led the scientific community to develop new methodologies and strategies to improve the design of our artefacts from an environmental point of view. Specifically, the cultural debate on the role of Design for Sustainability is focusing on the importance of adopting a circular and bioinspired approach to accelerate change: nature is once again becoming an important source of inspiration for the conception of an economic model of production and consumption that integrates technical cycles with biological ones, transforming the production and consumption model from linear to circular (Ellen MacArthur Foundation, 2013). Among the various emerging strategies for the design of our artefacts, the bio-inspired approach, or Biomimicry, is receiving more consideration for its innovative potential in promoting sustainability, offering new perspectives to address 21st century problems (Möller *et al.*, 2021) as potentially capable of accelerating the transition to a circular economic model (McDonough, Braungart, 2003; Salvia, Rognoli, Levi, 2009; Montana Hoyos, 2010; Cohen, Reich, 2016; Ruiz-Pastor, Chulvi, Royo, Sampaio, 2022).

Biomimicry proposes learning from nature rather than exploiting it as a resource, studying the 'character of nature' and consciously emulating the principles of adaptation and survival, understanding at a systemic level not only forms, functions and structures, but also processes and contexts (Benyus, 2002).

Literature Reviews and Research Objective

Man has always imitated nature in the design of his habitat and artefacts, replicating geometric and structural models of natural organisms. Today, thanks to nanoscience and nanotechnology, we can understand and innovatively replicate natural principles to create advanced products (Pietroni, 2011; Garg *et al.*, 2017). Nanoscience studies the unique properties of phenomena at the nanoscale, quite different from those observable ones at macro or micro scales. Such discoveries allow us to understand and replicate resilient and sustainable natural strategies, such as redundancy, hierarchy, modularity, autopoiesis, and adaptation. These strategies generate novel performances that, replicated through nanotechnology, allow designers to be able to use new materials with capabilities of, for example, superadhesion, hydrophobicity, and structural colour (Pietroni, Mascitti, 2016).

In parallel with the paradigm shift introduced by nanoscience and nanotechnology, the development of digital technologies in computational, parametric and generative design, together with rapid additive manufacturing, is evolving the way we design, transforming the traditional design and production criteria of industrial products (du Plessis *et al.*, 2019). Integrated and systemic approaches support bioinspired design by enabling the creation of products with advanced morphological-structural and technical-performance characteristics that would otherwise be unfeasible with traditional design and production processes, improving their sustainability (Pietroni *et al.*, 2024a).

While these premises are potentially valid, the results of the biomimetic approach should be critically questioned. Indeed, the 'biomimetic promise' (Gleich *et al.*, 2009) is often challenged in the literature (Kennedy *et al.*, 2015; MacKinnon *et al.*, 2020; Helmrich *et al.*, 2020) as biomimetic products do not always guarantee environmental qualities.

There is no guarantee that the biomimetic outcome will be efficient and this may depend on multiple factors: for example, the difficulty in abstracting and applying biological principles to technical design, the diversity of characteristics and constraints between the biological and technical systems, the possibility of achieving environmental benefits at some stages of the product life cycle counteracted by undesirable effects at other stages (O'Rourke, Seepersad, 2015). Furthermore, the literature points to the lack of a proven relationship between biomimetic design and sustainable design (Mead, Jeanrenaud, 2017). Although there are hypothesised tools for quantifying the sustainable potential of biomimetic products (Terrier *et al.*, 2019), a review of the literature reveals that the environmental benefits of the biomimetic approach in product design have rarely been quantified.

Indeed, the few bio-inspired projects and products that have been quantitatively assessed, using LCA methodology, include, for example, the case study on the environmental assessment of a bone-inspired ceiling structure compared to conventional lightweight ceilings (Antony *et al.*, 2014) and the environmental assessment of Lotusan® lotus effect façade paint compared to conventional Jumbosil® paint (Antony *et al.*, 2016), but little or nothing has been done on industrial products.

This last open question represents the focus that the doctoral research wished to explore, and therefore aims to verify the real advantages that the biomimetic approach can offer, in terms of environmental sustainability, to the design of industrial products. In accordance with the criteria of design for environmental sustainability (Vezzoli, Manzini, 2016), the research undertook an environmental re-design of an industrial product, certified with the EPD (Environmental Product Declaration), to verify, and then quantify, the environmental benefits that the biomimetic approach can offer to product design, going well beyond the application of established eco-design strategies. The article presents and discusses the conclusive and unpublished results of the doctoral research 'Biomimetic re-design of sustainable products. Increasing the environmental sustainability of products through biomimetic criteria" (Balsamo, Ph.D Thesis, 2023, Supervisor: Pietroni) concluded in 2023, the process and intermediate results of which have already been discussed in the article "Environmental Redesign of the Top San No Touch 2.0 Portable Toilet: The Contribution of the Bio-inspired Approach" (Balsamo, 2024).

Methodology and Tools of Design Research

Before starting the bio-inspired design experimentation process, research was conducted to identify and select the case study product to be used in the re-design phase. One of the main criteria for selecting the case study was that the product had obtained an environmental quality certification based on an LCA - Life Cycle Assessment study. The selection of the case study was carried out through a number of research activities: (i) the exploration of environmental quality labels for the industrial product, (ii) the collection, analysis and archiving of certified products, (iii) the application of specific selection criteria to identify the case study to be re-designed according to bio-inspired design principles (Balsamo, 2024). This preliminary phase led to the selection of the product TopSan NoTouch 2.0 by Sebach S.p.A., a leading Italian company in the rental of portable toilets. This product, in fact, obtained the EPD product environmental certification that contains a quantification of the environmental impacts associated with its life cycle, calculated through the LCA methodology.

Figure 1. TopSan NoTouch 2.0 portable toilet, Sebach S.p.A.

In the process of bio-inspired portable toilet re-design, an interdisciplinary approach was adopted, which is essential for the development of innovative and sustainable complex designs (Wissa *et al.*, 2022). This approach integrates expertise from biology, engineering and eco-design, involving experts from different disciplines. Furthermore, the systems approach, supported by advanced computational design tools, has accelerated the process of product design and optimisation (Pietroni *et al.*, 2024a).

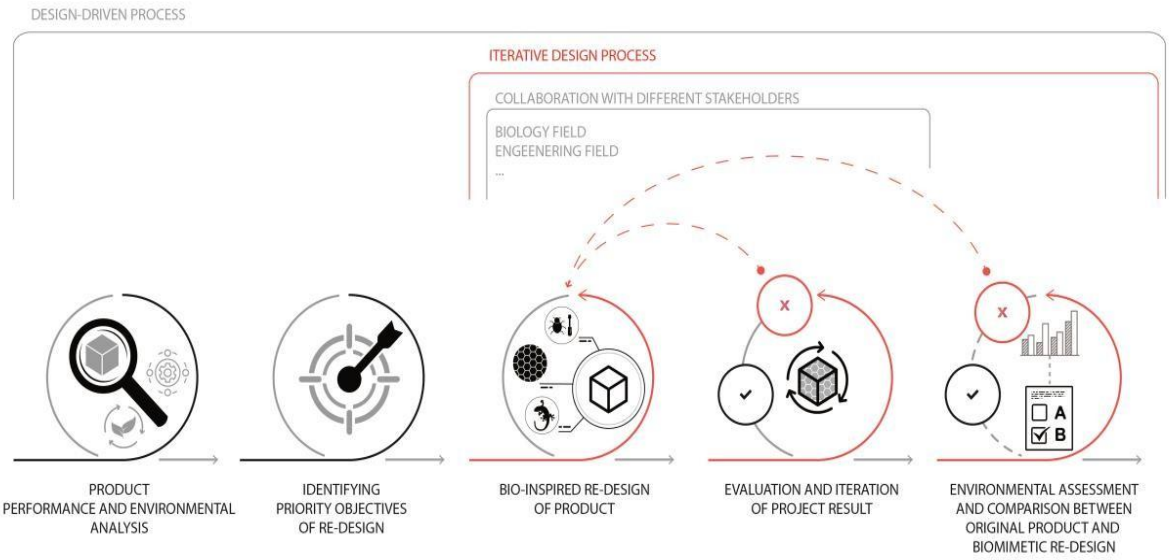

Figure 2. Methodological process for quantifying the contribution of Biomimicry to product environmental performance and increasing the eco-efficiency of industrial products. Image owned by the authors

It is therefore a design-led iterative process and, as depicted in Fig. 2, consists of five main stages, each of which is further subdivided as follows:

Step 1: Product performance and environmental analysis.

This phase is divided into: (i) Analysis of product performance, i.e. the formal and functional analysis of the portable toilet, as well as the collection of data relating to the company's production reality. The objective is to assess the current performance of the product in terms of functionality and efficiency; (ii) Environmental Product Analysis, i.e., a check on the environmental impact of the product using the Life Cycle Analysis (LCA) methodology in accordance with UNI EN ISO 14040 standards. This phase aims to quantify the environmental impacts associated with the product's life cycle phases. The LCA analysis was carried out using the ECO-it PRé Consultants software, which allows a simplified type of LCA study to be carried out, considered suitable for achieving the research objectives.

Step 2: Identification of priority re-design objectives and selection of the component to initiate the bio-inspired re-design phase

In this phase, the main objectives for product re-design are identified, focusing on how to improve product performance and reduce environmental impact through the bio-inspired approach, and deciding on which product component to start design experimentation.

Step 3: Bio-inspired product re-design

The bio-inspired re-design process involves the adoption of a top-down, interdisciplinary and systemic approach (Fayemi *et al.*, 2017, Pietroni *et al.*, 2024b).

Of fundamental importance are constant interactions with experts from the biological world in order to properly understand the solutions adopted by nature, with the support of specific databases and dedicated bibliography. The main steps, and related tools, are:

a- Exploratory research of biological models, to identify solutions from the natural world that correspond to the re-design objectives. This phase involves the systematisation of the main natural strategies and solutions that could be applied to the project;

b- Abstraction of the biological solution into design strategies. The identified biological functions and solutions are mapped and summarised graphically. The objective is to abstract these natural principles into design strategies that can be applied to product re-design.

c- Application of the biological solution to design development. The process of product re-design using biomimetic criteria is initiated. The transfer of biological solutions to the development of the new design of the portable toilet component in this research involved Structural Engineering researchers. The tools for design development include graphic representation techniques for the conception of the new design, software for 3D modelling in a parametric environment to have more control over the modifications to be made, specific software for the verification analysis of the functional performance that the product must possess and guarantee, and physical models for study and rapid prototyping using 3D printing for the precise verification of the formal and functional aspects of the new design.

Step 4: Evaluation and iteration of the design result

In this phase, the design result is evaluated by examining the performance of the new design against the set objectives, and any modifications are made to further optimise the design.

Step 5: Comparative environmental assessment between original product and biomimetic redesign

A comparative life cycle analysis (LCA) is performed between the original product and the biomimetic re-design to assess the effectiveness of the bio-inspiration in reducing environmental impacts. This last step allows the contribution of bio-inspired solutions to be quantified.

The TopSan NoTouch 2.0 Portable toilet by Sebach S.p.A.: Analysis, requirements and redesign strategies

In order to identify product environmental improvement objectives, a series of analyses were carried out to understand the formal, functional, performance and environmental performance of the portable toilet. This led to requesting the collaboration of the company Sebach S.p.A, which provided all the necessary resources for the research.

The TopSan NoTouch 2.0 portable toilet is a service-product, defined in the European standard UNI EN 16194 as a 'self-contained portable unit intended for use by a single person, equipped with a waste tank that is not connected to the sewage system'. Portable toilets are structured in a parallelepiped shape, with the major axis oriented vertically (cabin) and a square or rectangular base. The roof is usually curved or sloping to facilitate rainwater runoff down the sides, while the platform is equipped with side skids to allow lifting by forklift trucks. The side walls are fixed to the roof and platform to ensure structural solidity, and on one of the four sides there is a hinged door, opening outwards, which allows access for users. Inside the cabin is the toilet unit for the practical use of the portable toilet. From the study of the regulations, it was possible to extrapolate the quality requirements that the portable toilet must possess, and these are dimensional, accessibility and user safety, usability and comfort in use, and finally the minimum requirements inherent to the functionality of the toilet unit. The study of the regulations has made it possible to gather useful information to define the design constraints to be considered in the product's bio-inspired re-design phase.

Subsequently, in-depth analyses were conducted to understand the formal and functional characteristics of the portable toilet. Despite its simple appearance, the portable toilet is a complex product due to the essentiality of its components, which must meet high performance standards to be considered durable, easily assembled and disassembled. It is manufactured primarily through the injection moulding technology of high-density polyethylene, a material suitable for products that must be positioned in an outdoor environment. Then, following the physical survey of the product, sheets were created on its architecture, an abacus of the components and a summary of the performance requirements that the portable toilet must necessarily guarantee in the result of the bio-inspired re-design.

The second technical analysis aimed to assess the environmental impacts along the product's life cycle by integrating the missing environmental data in the Environmental Product Declaration. In that document, in fact, only summary tables of environmental impacts were reported (International EPD System, 2013, pp. 15-20). It was therefore necessary to rework the Life Cycle Assessment (LCA) calculation to identify the environmental impacts of the individual components of the portable toilet. This made it possible to identify environmental improvement options and thus initiate the bio-inspired re-design.

The functional unit (f.u.) adopted in the EPD was retained, i.e. ten years of use of the Sebach TopSan NoTouch portable toilet, while the system boundary considered in the new LCA calculation is the Cradle to Gate, i.e. the product life cycle stages A1- materials extraction, A2- transport of semi-finished products to the production site, A3-production, and A4- transport of the disassembled product to Sebach dealers.

The construction of the inventory (Life Cycle Inventory Analysis, LCI) was carried out by systematising the information present in the EPD and the material provided by the company, including the bill of materials, the 3D model of the portable toilet, as well as the physical product, placing the data in the relevant phases included in the System Boundary.

The calculation of the environmental impacts was performed with the ECO-it PRé Consultants calculation software that allows for simplified LCA analysis, whose reference database is IPCC 2007. By entering all the data collected in the calculation software, it was possible to compare the values extrapolated from

the analysis conducted individually with the values in the Environmental Product Declaration, resulting in equal environmental impacts.

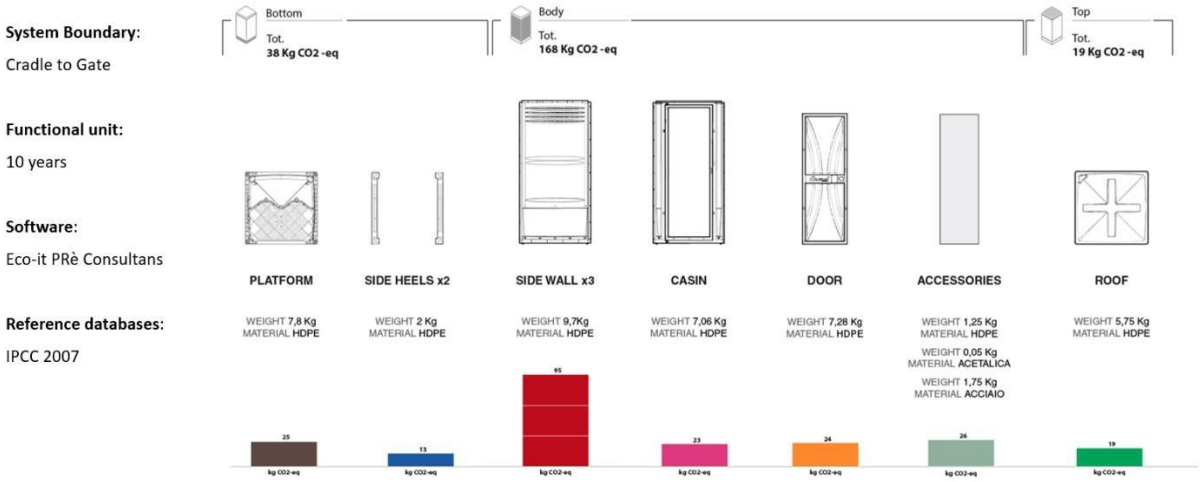

Figure 3. Summary scheme of the most impactful life-cycle components of the TopSan NoTouch 2.0 portable toilet including CO_2-eq values for each

As can be seen from the life cycle environmental impacts summary chart of the portable toilet (Fig. 3), the most impactful phase is the production of the plastic components of the portable toilet, constituting approximately 80% of the impacts in the Cradle to Gate system boundary.

Thanks to the possibility of being able to identify the environmental impacts of the individual components in the individual phases, the improvement considerations are oriented towards the macrocomponents that make up the portable toilet cabin (roof, side walls, boarding, door and footboard) for bio-inspired re-design. It should be noted that the re-design hypothesis excludes the toilet unit from the as the company's core business, i.e. the patented TopSan clean water system, is located within it.

Two re-design objectives were identified: the first objective aims to eliminate non-reversible joints, following the eco-design strategy to facilitate product assembly and disassembly. Currently, the portable toilet uses no. 73 rivets to connect the elements of the central body, preventing reuse in case of component replacement. The second objective is geared towards the eco-design strategy of minimising the consumption of environmental resources. In this context, it is intended to reduce the amount of material used in the production of components.

The central elements, such as the side wall (which is required in triplicate to form a portable unit) and the barrel-holder assembly, are injection-moulded in HDPE with a constant thickness of 4 mm to ensure rigidity and structural strength.

The start of the bio-inspired re-design phase focused on the side wall component that forms the central part of the portable toilet, covering three sides of the cabin. This component is of particular importance for the achievement of the two re-design objectives, both in terms of size and functionality, and as a nodal element for the configuration of the new reversible connection system.

Bio-inspired Re-design of the Portable Toilet: Interdisciplinary design process, tools, development and results

In the process of biomimetic design experimentation for the side wall of the portable toilet, the Topdown methodology was adopted: starting with the identification of a problem to be solved, the process continues with the solution-finding phase through analogies with the natural world, identification of relevant principles, abstraction of the biological model and application to the project.

The exploratory search for biological models was carried out by consulting specialised databases, such as the Biomimicry Institute's asknature.org, and consulting dedicated bibliographies. Interactions with experts from the natural world facilitated the exchange of information between design and biology. Using analogical reasoning, biological principles and strategies were identified to meet eco-design objectives for re-design.

To develop a reversible system of connections, the concept of 'temporary attachment' found in nature was explored, i.e., the connections that living organisms adopt to survive or evolve. Indeed, there are living systems that must stay in one place, climb or move, requiring the ability to release the cling when necessary. Although temporary, these connections must resist physical forces until they have achieved their purpose. Examples of these mechanisms include insects that attach their eggs to a leaf until hatching, and insects whose wings temporarily attach during flight and then separate after landing. Connections in nature are many, such as those of the caterpillar of the Gaia Oto butterfly or the hooks of the burdock, which inspired De Mestral to create the reversible Velcro connection. For the re-design of the product's connections, the principle of reversible attachment was abstracted, without the use of additional material, deriving the function directly in the parts of interest of the side wall.

In order to reduce the thickness of the wall component and use less material, the abstraction phase considered the strategy of structural resistance by shape, which is present in biological models such as the scallop. This organism possesses an extremely thin shell but retains considerable structural strength due to its surface deformation. Another useful approach to achieve this is the principle of element hierarchy, evidenced in the dense network of reinforcing ribs beneath the surface of the leaf of the Victoria Amazon, which suggests a rational distribution of material.

The process of transposing the identified natural logic to the design development was conducted by applying the biological principles to the technical functionality of the side wall of the portable toilet. Design constraints related to the material and the production technology, i.e., injection-moulded HDPE, were considered, as well as the formal-functional constraints of the component and the requirements dictated by current legislation.

The re-design of the bio-inspired reversible connection system focused on the assembly of the central body of the portable toilet, with particular attention to the vertical angles of the side wall. The new connection system involves hinges integrated directly into the mould of the component, creating movable parts that accommodate vertically developed quick-release couplings. These hinges alternate with fixed parts, allowing the movable parts of a wall to attach to the fixed parts of the corresponding corner and vice versa (Fig. 4). To complete the coverage of the central part of the portable toilet, the imbotte

component was also equipped with the new reversible connection system integrated into the corner pieces. This system creates a continuous module, allowing the central elements of the portable toilet to be assembled by hand. For the disassembly of the snap-fits, a specially designed accessory can be used: by inserting itself into the corresponding slots of each snapfit, this accessory can exert leverage on the pin, cancelling the snap-fit.

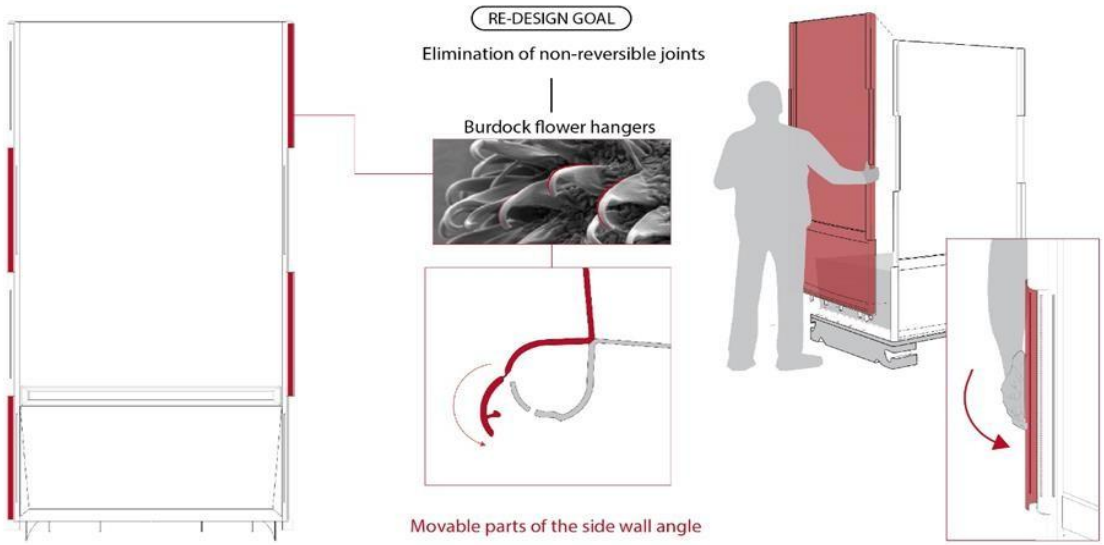

Figure 4. Burdock hooks whose function inspired the reversible giution applied to the side wall angles - highlighted in red. Image owned by the authors.

The area of interest of the side wall for the bio-inspired design development aimed at minimising material use was focused on the central part of the component. In order to understand how much material, it was possible to remove, it was necessary to identify the areas of the wall subjected to the greatest loads or stresses from, for example, the product handling phases that the authorised operator carries out when transferring the portable toilet from one site to another. This operation was made possible thanks to the topological optimisation of the component, i.e., the study, carried out with the Altaire Inspire software, capable of redefining the shape of the model, allowing the part to be lightened by subtracting unnecessary material in order to maintain its structural properties. In order to plan the analysis, it was necessary to involve researchers from the Unicam Structural Engineering area to define the characteristics of the 3D model, constraints and loads to be subjected to calculation, thus identifying two types of topological optimisation analysis.

The first analysis, pertaining to the application of the principles of structural resistance by form, aims to understand how the cabin structure reacts to loads from above (Fig. 5a); the second analysis, pertaining to the hierarchisation and rational distribution of material according to forces (Fig. 5b), was planned to understand the behaviour of the structure when subjected to horizontal loads (force that might be generated, for example, during vandalism). The topological optimisation operation follows the logic of emptying, and since the component cannot have any holes or openings, it was necessary to identify the main lines that constitute the base line for the bio-inspired re-design of the wall.

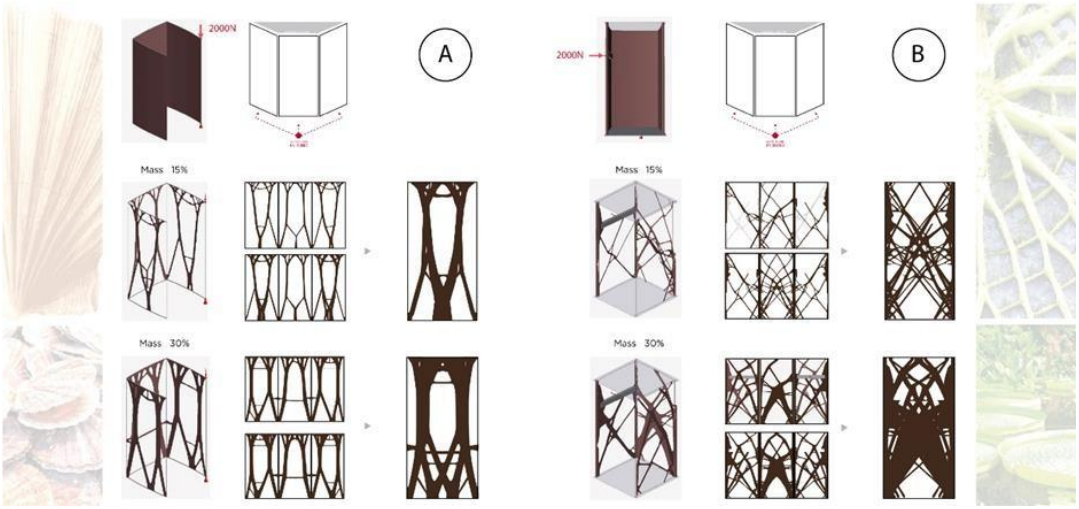

Figure 5. Summary scheme of the results that emerged from the topological optimization operation. Image owned by the authors

The process of formalising the component through biomimetic principles aims to reduce the constant 4 mm thickness of the current wall. Starting from a basic design modelled in a parametric environment and using the continuous structural evaluation by means of the OptiStruct analysis of the Altair Inspire software, it was possible to progressively refine the design until obtaining a model capable of guaranteeing the same structural strength as the current configuration.

Figure 6. Side walls compared: on the left front view of the current component, on the right the component re-designed bio-inspired. Image owned by the authors

The result is a side wall with a constant thickness of 2.6 mm, which is characterised by a surface movement: a base layer from which some areas of the wall protrude towards the outside of the car (in light red) and other areas retract towards the inside of the car (in dark red, Fig. 6). Due to the thinning of the thickness, the weight and material usage were significantly reduced. The original component had a constant thickness of around 4 mm and used 9.7 kg of high-density polyethylene. The bio-inspired side wall, on the other hand, has a constant thickness of approximately 2.6 mm, providing the same structural strength as the original component but using only 6.537 kg of HDPE.

Comparative Life Cycle Assessment: the benefits of the bio-inspired approach

At the end of the bio-inspired re-design, it was possible to start the comparative environmental analysis phase with the original product. The simplified analysis of the environmental impacts of the core body of the bio-inspired portable toilet takes into account the processes of the stages that define the system boundary 'from cradle to gate', i.e., from the extraction of raw materials to the distribution of the finished product. For this analysis, the ECO-it PRé Consultants software was used, software that works with Ecoindicators, choosing to return results according to the IPCC 2007 assessment method, which expresses CO_2 equivalent.

The production and assembly of the vertical elements that make up the central body of the portable toilet was taken as the functional unit of the LCA analysis, in order to evaluate in environmental terms the benefits of the re-design of the connection system between the elements that make up the portable toilet cabin and the re-design of the lightening of the wall component.

The Life Cycle Inventory phase (Baldo, Marino, Rossi, 2008), in which the input and output data are compiled and quantified, includes data collection and their calculation: the input data on the production and assembly flows of the central body of both the bio-inspired portable toilet and the current portable toilet were entered (Fig.7).

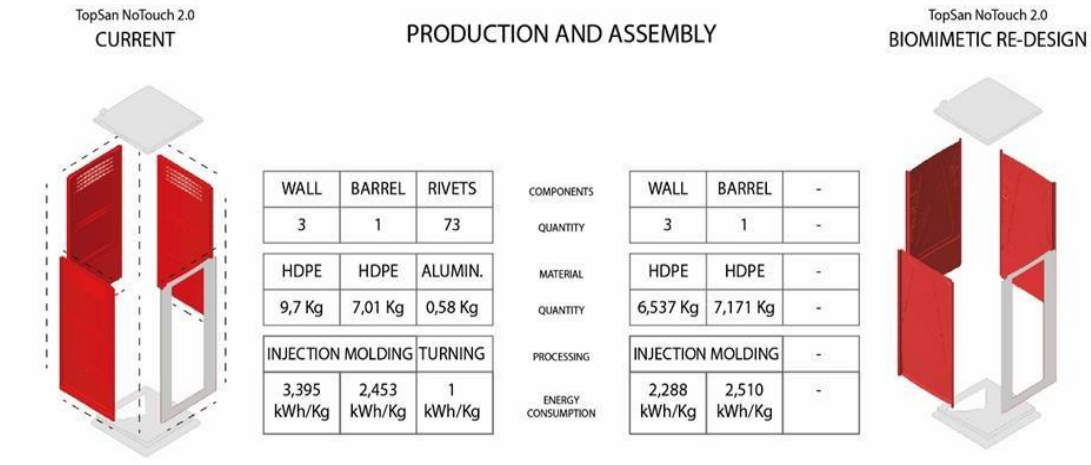

Figure 7. The inventory related to the production and assembly of the central body of the current mobile bathroom and bio-inspired re-design. Image owned by the authors

The results of the LCA calculation show that the emissions related to the production and assembly of the central body of the bio-inspired portable toilet is 87 kg CO_2-eq compared to 124 kg CO_2-eq of the current portable toilet. In percentage terms, this is approximately -28%, or -25 Kg CO_2 emitted into the environment.

A detailed analysis of the CO_2-eq emissions relating to the individual components shows a reduction in production of 19% between the bio-inspired wall and imbotte with integrated reversible connections and the corresponding current components. In addition, the reversible connection system between the components of the re-designed portable toilet core removes from the calculation the CO_2-eq emissions related to the rivets used in the current assembly of the TopSan NoTouch 2.0 toilet including the energy consumption due to the use of electronic tools to apply them.

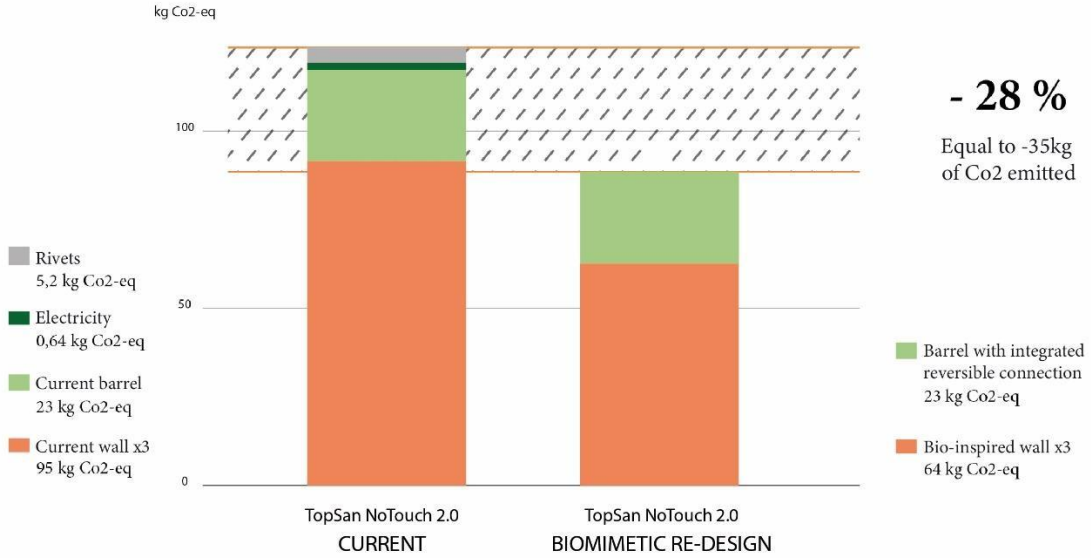

Figure 7. Analysis of environmental impacts. Co2-eq emissions for the production and assembly of the central body of the portable toilet. Image owned by the authors.

A further important reduction is related to energy consumption of -30%, a percentage that emerges mainly from the reduced use of high-density polyethylene for the injection-moulded production of the bio-inspired wall. The component re-designed according to eco-design criteria increased by the strategies abstracted from the natural world is characterised by a constant thickness of about 2.6 mm, guaranteeing equal structural strength performance with the original element, with a quantity of HDPE equal to 6.537 kg of material used. The comparison shows that the amount of material used to build the bio-inspired wall was reduced by 32% compared to the original. A percentage that is also reflected in terms of environmental impact, going from 95 to 64 kg of Co_2-eq for the production of the 3 components required to make an entire portable toilet. An important reduction if one assumes the annual production of 10,000 portable toilets. In fact, for the production of such a batch, 30,000 wall components must be produced, which currently corresponds to about 291,000 kg of material, while for the same number of productions of the bio-inspired wall, about 196,110 kg of HDPE are required. The design result generates advantages not only in terms of the quantity of material to be used, which translates into reduced environmental impacts, but also in terms of costs, thus drawing economic benefits.

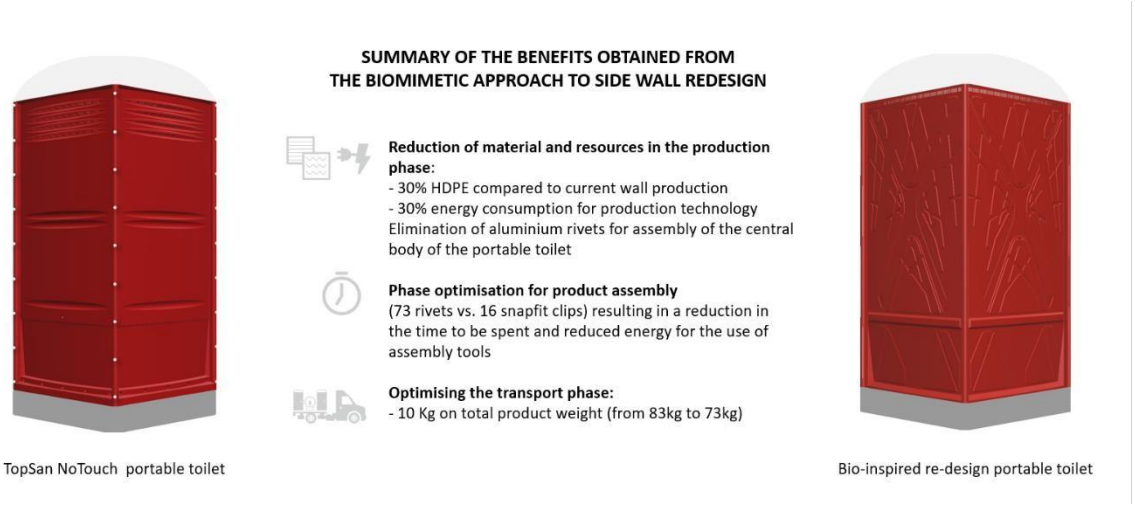

Figure 8. Summary of the benefits obtained from the biomimetic re-design approach to the side wall. Image owned by the authors

Further unquantifiable, but conceivable benefits are related to the post-production phases: the transport phase of the portable toilets to the location sites could obtain environmental benefits due to the reduction in the use of material in the production of the side wall, which decreases the total weight of the mobile toilet by about 10 kg, thus moving from the transport of a unit weighing 83 kg to a unit weighing 73.51 kg. Other possible benefits can occur in the rental service phases, i.e. maintenance and repair. Thanks to the reversible connections, rivets to be applied with specialised equipment are no longer required. This has advantages both in terms of time, as the Sebach operator can speed up activities without having to use tools, and in terms of costs, as new rivets are no longer needed to replace components or to customise the portable toilet in box module configurations.

Further Benefits of a Bio-inspired Design Approach

The comparison of environmental impacts focused on quantifiable aspects arising from the LCA calculation of the wall and the reversible connection system re-designed with the biomimetic approach. Further benefits to the development and production of the new component can be assumed in the possible application of currently commercially available bio-inspired materials. For example, the transparent Scratch Shield resin, developed by Nissan in collaboration with the University of Tokyo and Advanced Softmaterials Inc (Larin *et al.*, 2006), would be able to repair 80 per cent of surface scratches. The portable toilet is a product that is easily subjected to damage, such as vandalism, and to constant movement of the product, which can generate knocks or wear in some of its parts. Not to mention that the portable toilet is a product that is placed in outdoor environments, such as construction sites, events or near public beaches, which can deteriorate the surface qualities of the product over time. Therefore, the application of resins with self-repairing capacity would guarantee an extension of the life of the surface quality of the portable toilet components most subject to wear, eliminating the use of chemical agents for restoration.

Lotus-effect' surface treatments, on the other hand, could provide greater hygienic safety and ease of cleaning. The most famous natural example of self-cleaning is found on the leaf of the lotus flower. Researchers have attributed this characteristic to highly water-repellent nanostructures known as micropillars. Water resistance and self-cleaning are ideal characteristics for plastics, so much so that scientists are now investigating artificial production methods for nanostructures capable of activating these properties or coatings and surface treatments capable of mimicking the capabilities of the Lotus leaf. The latter include Nano Coating for Plastic by the company Nano Clean Solutions© (http://www.nanocleansolutions.com), a transparent hydrophobic coating that makes the treated surface water-repellent, thus protecting it from dust, insects, dirt and UV rays. By applying such a coating, the use of detergents is reduced by 90% as it protects against bacteria, mould and fungi.

Conclusions

The research process just described aimed to answer a question raised in the literature about the proven relationship between Biomimicry and Sustainability. In detail, the main objective was to quantify the benefits that the bio-inspired approach can offer over and above the established eco-design guidelines and strategies. The aim was to undertake a re-design of a product already manufactured according to eco-design strategies and in possession of environmental certification, in order to re-design it in a Biomimicry-inspired key and to quantitatively assess the contribution offered by Biomimicry, analysing the benefits obtained through comparative analyses between the case study product and its bio-inspired re-design.

The design development had to meet important requirements in order to achieve a truthful quantitative assessment of the environmental impacts of the re-designed components: the high degree of production feasibility consistent with the reference company reality of the case study, the technical and regulatory requirements of the product, and a design consistency of the formal, functional and performance aspects to be maintained in the new product.

The process of bio-inspired re-design of the parts of the product considered to be a priority and the subsequent environmental assessment, carried out following the standardised Life Cycle Assessment method, allowed the comparative analysis between the result of the design development conducted and the original TopSan NoTouch 2.0 portable toilet product. The results of this comparative analysis thus made it possible to answer the research question, achieving the objective of quantifying the benefits that the biomimetic approach can offer in the design of industrial products. The results show that Biomimicry can concretely contribute to the generation of more sustainable products, and that the relationship between Biomimicry and eco-design appears to be a promising synergy for the development of a new generation of low environmental impact products.

In the course of this research, a significant result emerged in terms of methodology. Each stage of the process required the adoption of specific methodologies and tools. For example, the environmental assessment was quantified using Life Cycle Analysis (LCA) methodology and tools, while the biomimetic approach involved interaction with biology experts and consultation of specialised databases. Advanced software and continuous comparisons with structural engineering researchers were used for the development of the bio-inspired design. The interdisciplinary aspect proves to be crucial for the realisation of complex research projects such as this one. Finally, the acquisition of specialised knowledge

along the entire research path leads to reflections on the role of the designer, who takes on a different role than in the past, especially in complex research contexts. This new role requires the integration of knowledge from diverse approaches, methodologies and operational tools, enabling the designer to play a central role in the management of research processes of this nature.

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Ecodesign-Based Modelling of Decarbonisation

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Abstract

Decarbonisation, as reducing or eliminating greenhouse gas emissions, is a vital goal in mitigating climate change. This process requires the application of eco-design models and practices. The main goal of our research was to determine the possible ways of decarbonisation in a research institute with 300 employees. The applied methods were a review of literature, scenario building, carbon footprint (CF) calculation and comparative analysis—the modelling of CF calculation based on MSZ ISO 14064 standard. This paper investigates the CF value of the same period of 2 different years, considering real data on office working (2020) and remote working (2021) when 90% of employees were at home due to the pandemic and created a new hybrid scenario. The embodied carbon content was neglected. The functional unit was the carbon footprint created by one person in one hour. The results showed that the critical elements of CF are commuting and travelling abroad. Those have higher CF values than the CF of direct and indirect energy usage together. However, 20-55% savings can be achieved, and the biggest can be mainly achieved by increasing the flexibility of working hours and promoting remote work. This suggests a potential for positive change in our carbon footprint, inspiring hope for a more sustainable future. However, energy consumption at home has increased.

Introduction

Eco-design plays a pivotal role in achieving decarbonisation goals by integrating sustainability principles into the design of products, services, and systems. Decarbonisation, as reducing or eliminating greenhouse gas emissions, is a vital goal in mitigating climate change. There are more possible ways of eco-design models and practices through:

- Energy efficiency
- Renewable energy usage
- Material selection and LCA
- Adaptation of circular economy principles
- Digital technology
- Smart design, and
- Moving to the virtual world

There are many scientific publications on eco-design decarbonisation and digitalisation. The science direct search of “impact of work from home” resulted in 53000 papers in 2024 and 28000 in 2019, „digital decarbonisation” appeared in 439 papers in 2024 and 79 in 2019, while “eco-design decarbonization and digitalization” appeared in 104 papers in 2024 and 7 in 2019. For example, the impact of work was addressed by Bachelet *et al.,* 2021; Hill *et al.,* 2023; digital decarbonisation by Fouquet et Hippe, 2022; Pauliuk *et al.,* 2022; and Pierce *et al.,* 2024.

Last year, we studied the impact of digital decarbonisation in various areas (higher education, conferences, workplaces), but in this article, we focus only on digital decarbonisation of workplaces. Eco-design modelling requires comparing traditional work with work in the digital space. The differences in impact are well-measurable.

The characteristics of conventional work are as follows: It has a fixed location of the firm or company's office, factory, or store. It typically has set working hours, such as 8:00 am to 4:30 pm - with 30 minutes' lunchtime. There are in-person communication and face-to-face interactions. It involves Many business trips, and the work environment is supervised. Need formal dress code. The offices are equipped with the necessary tools, equipment, and technology – and the workers use the infrastructure of offices.

Working has changed during the COVID-19. Locking down increased the number of jobs from home (Carbon Trust, 2021), which increased the number of distance work, hybrid work, and home offices in the World (Akgüç, Galgóczi és Mei, 2023). Face-to-face interaction replaced internet-based communication, such as TEAMS, Zoom, or Go to Meetings. Decreased commuting - the travelling from home to workplaces and business trips, and decreased transport (IEA, 2020). Working from home does not require formal dress codes. Reduced the usage of office infrastructure (Obringer *et al.* 2021) – increased IT usage at home. This can be measured by decarbonisation (Bachelet *et al.,* 2021).

Our research aimed to determine how to decrease the company's carbon footprint in the future, especially moving to the virtual space; which kind of eco-design practice should apply? Among the aims were the following too: the monitoring of energy consumption, as well as the sensory tracking of heating and lighting, the improvement of efficiency in the use of electrical equipment, intelligent automation and IoT (Internet of Things) and mainly the reduction of commuting-related impacts. The function unit was the carbon footprint per person per 1 hour. Besides these, our objective was to determine the cost of decarbonisation.

The reference office was an institute of the construction industry. The construction industry is responsible for 39% of global carbon dioxide emissions (WBCSD, 2021) and most global material use, with concrete and bricks accounting for 50% and steel accounting for 40%. Considering the expected 60% increase in the urban built environment by 2050 (UNEP, 2013) and the significant demand for the renovation of urban housing (European Commission, 2019), decarbonisation (i.e., the reduction, elimination and/or reduction of greenhouse gas emissions from processes or removal) is critical to meeting the climate change mitigation goals set out in the Paris Agreement. During the entire life cycle of buildings, carbon dioxide emissions appear at several points, which can be built-in (material extraction and production, transport of building materials, building construction, maintenance, replacement, renovation, repair and end-of-life management) but can also come from operation (use of buildings, heating, cooling, lighting, use of electrical devices).

Decarbonisation, which reduces or eliminates greenhouse gas emissions, is a vital goal in mitigating climate change. There are more possible ways of eco-design models and practices are through:

- Energy efficiency
- Renewable energy usage

- Material selection and LCA
- Adaptation of circular economy principles
- Digital technology
- Smart design
- Moving to the virtual world

In the last 5 years, the number of scientific publications has almost doubled, both concerning decarbonisation, digitalisation and eco-design.

Literature Review

According to Dingel and Neiman (2020), around 20% of jobs worldwide could be done from home. While this ratio drops to 10% in countries south of the Sahara in Africa, it exceeds 45% in the richer countries of Europe. For workers, the alternative is often a long commute to central workplaces, contributing to cities' already high carbon dioxide emissions and air pollution. Wherever the reduction of carbon dioxide emissions and energy consumption is realised, it can be seen as a positive development, but the environmental effects are always a global problem. International differences in environmental protection practices often limit the prospects for long-term sustainability of impacts. When assessing the environmental effects of teleworking, many factors come into play, and their effects are often intertwined. Based on the research of Akgüç, Galgóczi and Mei (2023), the ecological effects can be classified into 3 groups.

Table 1. Classified of ecological effect of teleworking

Environmental effects	Energy consumption	Mobility
• Geographical location of remote work (rural or urban development) • Noise and air pollution • Use of mineral and other natural resources • Energy consumption the general carbon dioxide intensity (IT) of the energy used is the energy consumption of devices used in the office and at home	• The way the office premises are used (e.g. fixed or flexible telecommuting days, hotdesking and the planning of energy consumption systems during this time). • energy performance of • office and residential buildings • the size of the apartments and office premises • the type of heating or cooling systems of the office and residential building • the number of persons working from home in the household • the geographical characteristics and seasonal dimensions of the locations (e.g. the length of the winter or summer months) affect the heating or cooling demand of the buildings • the general carbon dioxide intensity (IT) of the energy used is the energy consumption of devices used in the office and at home consumption habits	• the distance between the workplace and the place of residence • availability of • (sustainable) public transport • the energy performance of the mode of transport during work • fuel efficiency of • passenger cars mobility habits outside the workplace

The literature on telecommuting is not yet complete from an environmental perspective, but existing studies focus primarily on CO_2 emissions (Bachelet *et al.,* 2021; Cerqueira *et al.,* 2020; Eurofound 2022;

Carbon Trust 2021; Ecoact 2020), which are associated with reduced transport and generally refer to car use as sustainable public transport.

Employees' transport habits, energy consumption, use of IT and other work-related devices, and the prospects of remote working are crucial for decarbonisation. For remote work to be sustainable and have a positive effect, the research must clarify its actual environmental effects compared to the working habits of the period before the pandemic.

While detailed data on CO_2 emissions are increasingly available at an aggregate level, facilitating the development of quantitative models to estimate the relationship with teleworking, the same cannot be said for the other environmental metrics mentioned above, which partly justifies the focus on emissions. Another simplification of telecommuting is only to consider working from home since this is one, but not the only, type of telecommuting. Focusing on working from home to understand environmental impacts reduces the complex dimensions associated with outsourced telework along global value chains, making environmental traceability difficult.

According to a comprehensive global analysis by the IEA (2020), in the first phase of the COVID-19, gasoline use fell by more than 9 million barrels per day (plus 6 million barrels of diesel) after the shutdowns. In addition, in many large cities worldwide, congestion during rush hour has been significantly reduced, for example, by 65-95%. These effects of comprehensive restrictions and closures indicate the effects of reduced mobility through teleworking, but they can only be considered a starting point.

A comprehensive global analysis of the first phase of the lockdowns showed that working from home increases household energy consumption by 7-23% a day, depending on several factors, including the energy efficiency of homes and the number of people working remotely in a household. It has also been shown that with telecommuting, the proportion of energy consumption during the working week is similar to the average energy demand on Sundays when most people have the day off and are at home (IEA 2020).

Bachelet *et al.* (2021), using the German micro census and the corresponding energy and carbon dioxide prices, suggest that while telework increases annual heating energy costs per employee by 110 euros, it reduces annual transportation expenses per employee by 840 euros. From the point of view of the ecological footprint, the general effect of telework is not apparent. In their Canadian study, Lachapelle *et al.* (2018) said that telecommuting increases productivity and, thus, economic growth, which is likely to lead to increased production and income. Thus, an increase in consumption patterns (e.g., more leisure travel, more on necessities, increased consumption of surplus goods, etc.), increases the general energy demand. In this case, although telecommuting would theoretically reduce emissions by reducing commuting as a first-order effect, it may result in a larger total ecological footprint due to increased consumption and higher energy demands.

In addition, the increased use of telecommunications and the heating of homes often hurt the climate. Whether companies develop strategies to reduce their office space (and thus their energy consumption) is questionable. Previous research shows that IT equipment has had dynamic energy consumption in the last few years. The literature on the subject is still emerging, but according to Efoui-Hess (2019), digital technologies already accounted for nearly 4 per cent of global carbon dioxide emissions even before the pandemic - more than aviation - and their impact every year, increased by 8 per cent. In other words, ICT

tools essential for remote work are significant sources of emissions. Relatedly, Obringer *et al.* (2021) point to the carbon footprint of Internet use (related to energy consumption in data and cloud centres), which ranges from 28 to 63 grams of CO_2 equivalent per gigabyte. Among the various Internet services, the most frequently used devices, such as video conferencing, were identified as the option with the highest energy consumption. However, technological development in this area is continuous, and more energy-efficient solutions are being created (Obringer *et al.*, 2021).

The main potential benefit of telecommuting is mainly related to its role in reducing mobility. It is well known that transport significantly contributes to greenhouse gas emissions and that commuting (from home to work and back) accounts for a large part of it. The growth and role of telecommuting are becoming increasingly important in sustainable mobility (Aguiléra and Pigalle 2021), as telecommuting or hybrid work is often cited as one of the primary means of reducing carbon dioxide emissions, i.e. the level of commuting is lower.

According to a study by Bachelet *et al.* (2021) investigating the environmental effects of telework, the reduction in emissions due to the reduction in car commuting amounts to 4.5 million tons of CO_2, which corresponds to 3% of the carbon dioxide emissions of the German transport sector. The figures vary according to income groups and the employees' place of residence. According to the ADEME (2020) estimate, 271 kg of CO_2 could be saved per year per person and one day per week in France by teleworking, differentiating the different emission methods (e.g. transport, ICT devices, delocalisation of energy demand) and adding them together. Beck *et al.* (2020) state that telecommuting reduces car commuting. Like the ADEME report, Beck *et al.* point out that the number of days spent working at home is crucial. Eurofound (2022) also conducted a case study in Ireland - which had the third highest rate of teleworking in the EU after the pandemic - and found that teleworking has a favourable climate impact, saving 164,407 tonnes of CO_2 emissions per year. Kylili *et al.* (2020), per 100 employees in Cyprus, at least 4 litres of transport fuel and 7.4 kg of CO_2 emissions can be saved with one hour of remote work.

According to the research of Krasilnikova and Levin-Keitel (2022) on an industrial suburban area of Hannover, Germany, 59% of the workers in the area have the opportunity to contribute to reducing car traffic through remote work. This area is home to many leading national, international, and local companies. The study also finds that only 5% of telecommuters work full-time from home (the majority 1-3 days a week or less). The authors calculated that two additional telecommuting days would result in an 11% CO_2 emission savings. The research also points out that the role of companies is crucial in supporting, enabling and promoting remote work. A supportive corporate culture includes digital work and a broader transformation of business models and human resources policy.

Remote work can not only result in reduced traffic and travel but also contributes to the valuable use of free time, recreation, community programs and the development of an active social life - with shopping opportunities, cultural offerings or simply because of meetings.

Methodology

The methods used during the research were as follows: literature processing, selection of a reference office and modelling of the carbon footprint calculation setting up scenarios and data collection for the same period of two years (collecting the actual, measured data of the office and calculating the estimated

data for commuting and meals based on a questionnaire survey), determining the carbon footprint and conducting comparative analyses to determine the possible decarbonisation paths.

The examined building is an office building with 2 floors, which uses energy-saving and environmentally conscious structural and mechanical systems and is located in the county of Pest, 20 km from Budapest. Main net floor area data: ground floor: 1943 m^2, I. floor: 1869 m^2, II. floor: 1873 m^2, total 5685 m^2. An extensive green roof is on part of the roof, a green facade is on part of the façade, and an air-conditioned facade was also created. The new facility, handed over in 2013, implemented the most modern, environmentally conscious and energy-efficient solutions in its architectural and technological methods. The office building was built with low-temperature ceiling heating, heat pump cold and hot energy supply based on wastewater, gas-fired combined electricity and heat production.

The data necessary to set up the model underlying the decarbonisation calculations and define the methodology were collected for 2 periods. In February 2020, many employees worked in the office; sometimes, telecommuting was permitted (family reasons or transportation problems). On the other hand, in February 2021, after the end of the emergency due to the COVID-19 pandemic, it was possible to request work from home to minimise the number of people working in the office. On the other hand, at least 1 person per shift had to stay inside.

Data collection was carried out for the office building that forms the basis of the reference model and for the input-output currents defined in the model. The data influencing the carbon footprint development were taken into account based on the measured data of the competent offices (operations, IT, HR), with an allocation that considers the actual area and staffing data.

The carbon footprint calculation methodology followed the Greenhouse Gas Protocol and the ISO 14064 standard for organisational carbon footprints, and we performed the calculations accordingly. We did not consider the carbon content embodied in the building because its determination would go beyond the scope of this research.

The formula used in the calculation is as follows:

CFwp =∑(i=1)^n CFi,

where:

CFwp: workplace organisational carbon footprint

CFi: factors involved in the formation of the carbon footprint, Detailed:

CFWp = ∑CFdirect + ∑CF indirect + ∑CF other,

where:

CFdirekt: direct emissions,

CFindirect: emissions related to indirect energy (electricity)

CFOther: other indirect emissions, ie

∑CFother = CF transport + CF foreign travel + CF business partner + CF meals + CF waste

+ CF water consumption

The carbon footprint can be calculated according to the following relationship:
CF = Q * f CF, where
Q: the amount of the factor causing carbon dioxide (kWh, kg, m^3, km, dose) f CF: emission factor for the given factor

Modeling the Work Investigation and Presenting the Analysed Scenarios.

During the investigation, the factors shown in Figure 2 were calculated according to the division according to SCOPE. In the calculation, the carbon footprint of each factor is determined separately and then aggregated. The emission factors used in the calculation come from the Ecoinvent database, based on the IPCC 2021 impact category (GWP 100). The input and output quantities of the life cycle inventory are actual or calculated data, the basis of which was provided by KSH data, databases and literature data.

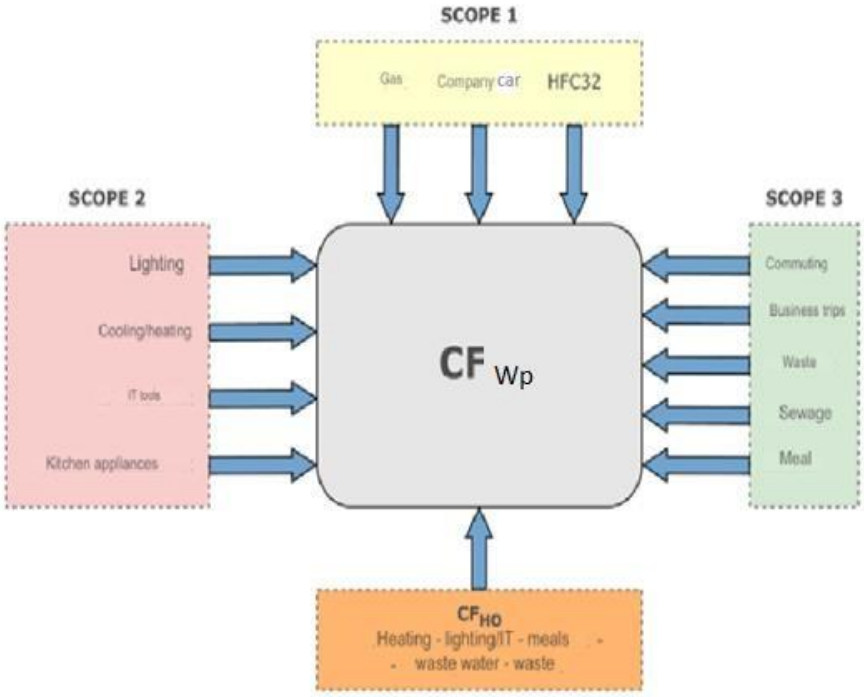

Figure 1. Modelling of carbon footprint by SCOPEs (own editing)

The life cycle assessment does not cover the examination, maintenance, and renovation of the office supplies required for office work, nor the embodied carbon content of the office building and electronic devices.
The function unit:

- Carbon footprint of office work, respectively
- Carbon footprint created by one person in 1 hour

Based on actual data, the analysis followed the MSZ EN ISO 14064 standard, according to the SCOPE 1-2-3 classification of the factors causing direct and indirect emissions. It was estimated based on literary sources and statistical data.

The scenarios are listed in Table 2. The hypothetical scenario S-3 was based on the actual data of S1 and S-2. The comparison is carried out in a complete system, taking into account the elements of working at home that were taken into account when working at the workplace (heating, energy use, etc.) The inventory was recorded in all three scenarios after data collection, as specified in Table 2.

Table 2. Description of scenarios

Scenarios	Description
Base case (S-1) scenario	100% of employees come to work; working from home is impossible. Based on real, measured values for February 2020.
Working at home (S2 Scenario)	90% of employees work at home, and only 10% must be present. Based on actual values for February 2021.
A hybrid solution (S-3) scenario	It is possible to work from home, which affects 20% of employees, so 80% come to work.

Table 3. The data underlying the study

SCOPE 1	Gas consumption	MJ	real data of workplace
	Company's car usage	km	measured
	HFC 32	kg	estimated
SCOPE 2	Lighting	kWh	calculated based on performance and working time
	IT tools	kWh	calculated on based inventory data and performance of tools
	Heating/Cooling	kWh	calculated
	Kitchen equipment	kWh	calculated
SCOPE 3	Business trips	km	calculated based on a database of the office
	Commuting	km	calculated based on the survey
	Meal	kcal	estimated
	Waste	kg	estimated
	Water consumption	m^3	measured
Working from home	Working from home _S2 Heating	MJ	Calculated based on statistical data
	Lighting/ Electricity	kWh	Calculated based on statistical data
	Eating	kcal	calculated based on survey
	Waste	kg	Calculated based on statistical data
	Water consumption	m^3	Calculated based on statistical data

Results and Discussion

First, we present the possibilities of each alternative separately from the point of view of the workplace, broken down by area of influence. The carbon dioxide equivalent (kgCO_2e) from direct emissions of SCOPE 1 is shaped by the emissions of own vehicles, as seen in the figure. In the S-2 scenario, the use of own vehicles was minimal compared to the case of working in attendance. In scenario S-3, when 20% of workers work from home, the reduction is 20% compared to scenario S-1. For comparability, the CF results refer to the work of 1 employee for 1 hour (CO_2 equivalent/person/hour.

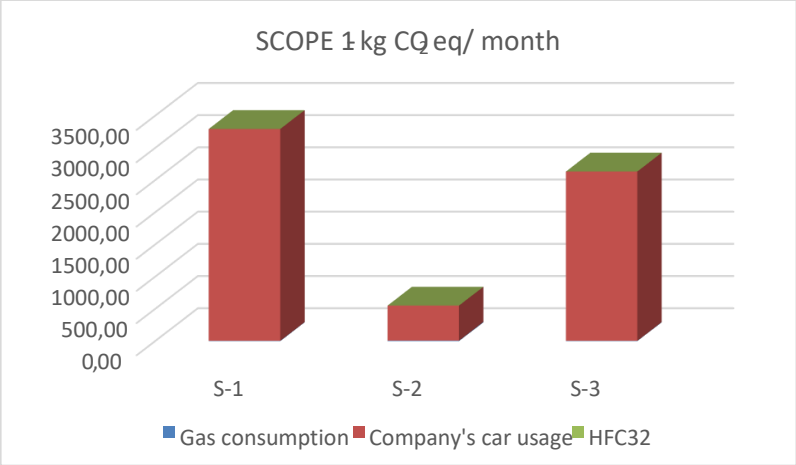

Figure 2. SCOPE 1- Carbon footprint of direct emissions kg CO_2e/person/hour (own editing)

Examining the development of indirect emissions resulting from energy use (SCOPE 2), it can be concluded that the workplace's electricity consumption decreased in addition to working at home, so the possibility of working at home can result in environmental benefits for the company. The figure shows the significant differences. Working 90% from home resulted in a 63.4% reduction in carbon dioxide from electricity used, and even 20% telecommuting resulted in a 15.4% reduction in greenhouse gas emissions for the company.

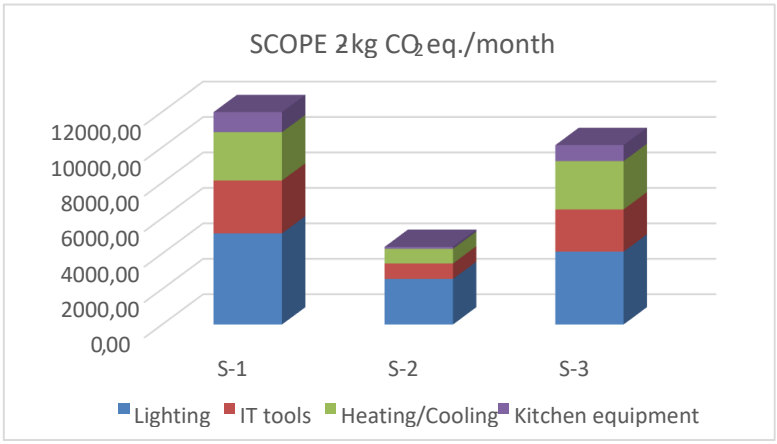

Figure 3. The development of the greenhouse effect from electricity in the 3 scenarios (own editing)

Areas belonging to the SCOPE3 area - business trips, commuting, eating, waste and water consumption, as indirect greenhouse effect generators, resulted in even more significant differences. 90% working from home resulted in an 87.5% reduction, while 20% working remotely and on-site workers reduced the organisation's carbon footprint by 20.4%.

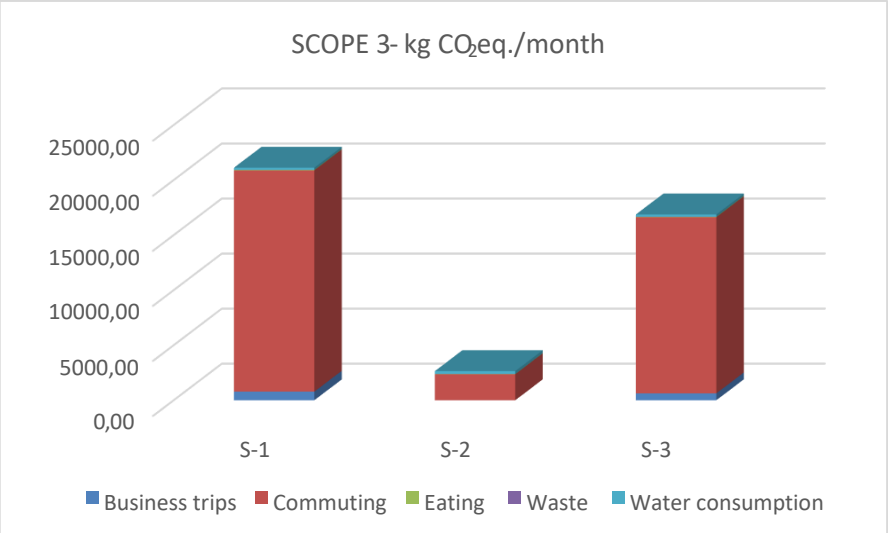

Figure 4. Evolution of greenhouse gas emissions in SCOPE 3 area (own editing)

A joint examination of the mandatory SCOPE 1 and SCOPE 2 areas for carbon footprint calculation (presence + working from home) shows that the shift towards working from home reduces CO_2 emissions.

Our assumption that the energy use of working from home neutralises the reduction in greenhouse gas emissions from commuting as a rebound or boomerang effect is completely overturned. Examining the carbon footprint of business trips and commuting with the digital transition, the overall greenhouse effect was reduced by half in the S-2 scenario and 10% in the S-3 scenario.

When reporting the environmental values of the organisational carbon footprint, it is mandatory to determine the values of SCOPE1 and SCOPE 2, which include the consumption of natural gas used for heating, the emissions of air conditioning equipment, the data of the vehicles owned by the company, and the consumption of electricity. In the basic S-1 case, the effects related to SCOPE 2 -electricity consumption- are dominant. In the S-2 scenario, this value decreases by more than 40%, even though the workers consume more energy at home than in the base case. If a hybrid solution (S-3) could be implemented, the effects would be reduced by 10% compared to the original base case (S-1). Breaking down the individual SCOPE distributions, it can be seen that:

- the values of SCOPE 1 are largely unaffected by where the employees work, and the effects of working from home are even slightly greater than those of working full-time,
- there are already significant differences in the distribution of the effects of SCOPE 2 energy use clearly, working from home provides a good solution from an environmental point of view,
- SCOPE 3 has the most significant role in this study, especially in the scenarios where the role of going to work is dominant.

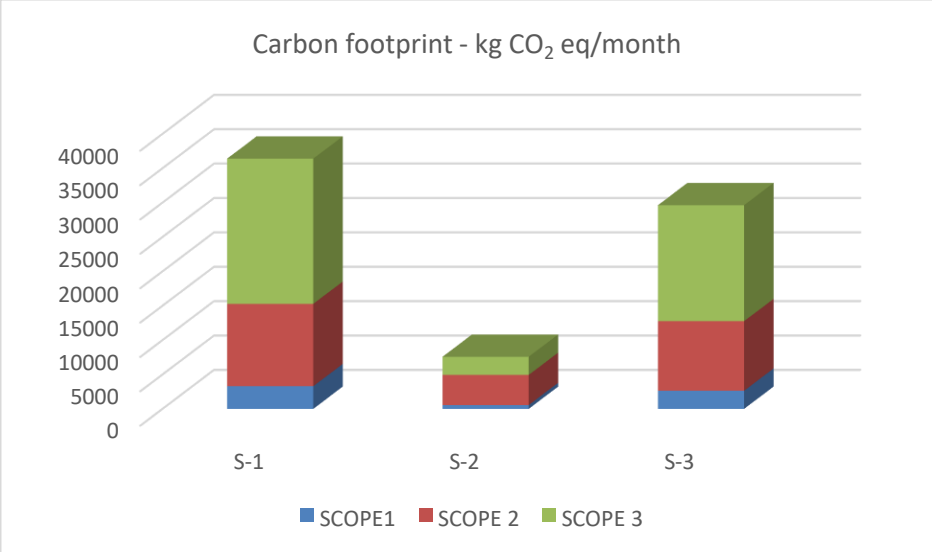

Figure 5. The Carbon footprint of the office per month

The first scenario (S-1) has the highest impact of the three examined scenarios, followed by S-3 and S-2 with the smallest impact. In all cases, the effects of commuting increase the results, but the use of a company car, which was minimal in the case of S-2, also increases the effect.

Table 4 shows the total monthly carbon footprint values for the operation of the examined office building and the carbon footprint of working from home per person based on one hour of work.

Table 4. Carbon footprint values per person per 1 hour

Working type			**kgCO₂e/Scenario**		
			S-1	**S-2**	**S3**
Working in office	SCOPE 1	Gas consumption	1.32E-04	1.93E-04	1.06E-04
		Company's car usage	8.16E-02	1.35E-02	6.53E-02
		HFC32	1.46E-07	1.46E-07	1.46E-07
	SCOPE 2	Lighting	1.27E-01	6.37E-02	1.02E-01
		IT tools	7.39E-02	2.16E-02	5.91E-02
		Heating/Cooling	6.77E-02	2.05E-02	6.77E-02
		Kitchen equipment	2.79E-02	2.79E-03	2.24E-02
	SCOPE 3	Business trips	1.93E-02	0.00E+00	1.55E-02
		Commuting	4.99E-01	5.86E-02	3.96E-01
		Eating	9.45E-04	4.73E-04	9.45E-04

Working type			kgCO2e/Scenario		
			S-1	S-2	S3
		Waste	3.99E-05	4.56E-05	3.65E-05
		Water consumption	4.93E-03	6.47E-03	5.18E-03
Working from home	SCOPE 1	HO_S2 Heating	0.00E+00	7.88E-02	1.75E-02
	SCOPE 2	Lighting/Electrical tools	0.00E+00	2.25E-02	4.44E-03
	SCOPE 3	Eating	9.45E-04	4.30E-03	3.78E-03
		Waste	0.00E+00	3.17E-02	7.04E-04
		Water consumption	0.00E+00	4.07E-02	9.04E-03
Total		Total	**9,03E-01**	**3,66E-01**	**7,70E-01**

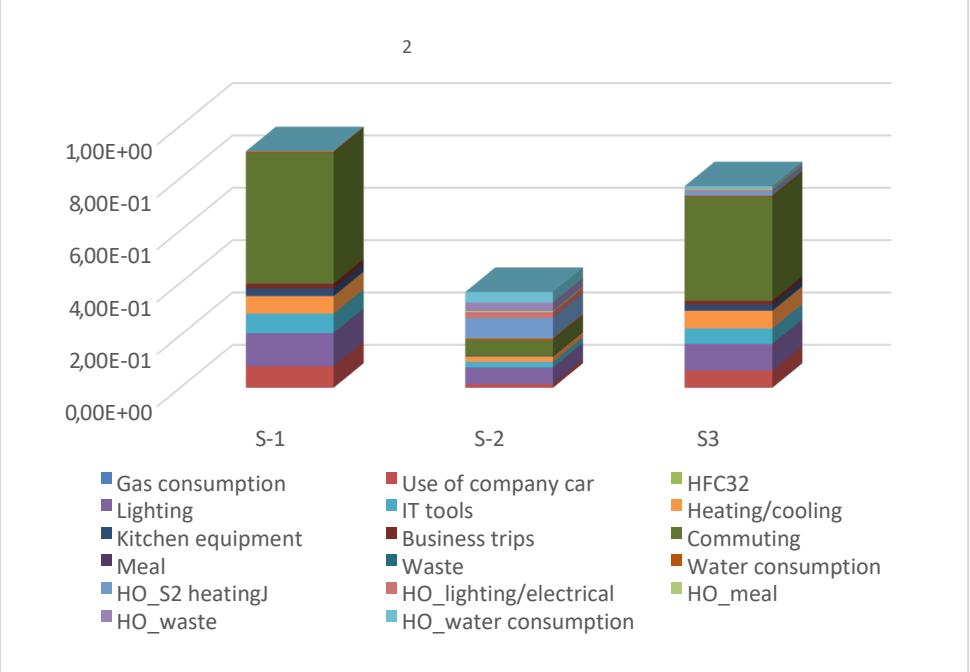

Figure 6. Carbon footprint per capita per 1 hour

CF (kg CO_2 eq) per capita per 1 hour

Conclusion

Although telecommuting can indeed have a positive impact on the environment, in reality, it depends on many other factors and the degree to which they are used. As a combination of remote home offices and

office presence appears to be the most common model in most sectors and occupations, the effects of the green transition are likely to be limited to reduce commuting and smaller reductions in energy and infrastructure emissions associated with maintaining office buildings. Despite this, more and more scientific literature proves that the main source of the positive climate and environmental impact of teleworking is the reduction of commuting between the workplace and home due to less emissions.

Some studies have also shown that the benefits depend on the combination of transport modes, work schedule (number of telecommuting days, full-time or part-time) and settlement structure. In addition, they also highlight that if remote work takes place within the same lifestyle and work organisation framework, using the same settlement structures and transport infrastructure as planned for full-time office work, then it cannot mean a change in sustainability. Even the resulting carbon footprint - or, in a broader sense, ecological footprint can be even worse.

Our research also confirmed that the effect of remote work on energy consumption is contradictory.

While home energy use increases, office energy use does not necessarily decrease with hybrid solutions.

The research revealed possibilities for decarbonising the examined office. These include energy review and development, improving the energy efficiency of office equipment, using renewable energy, and using environmentally friendly lighting, cooling, and air conditioning. Furthermore, a proposal for greening the commute emerged.

Developing policy measures to promote the positive effects of teleworking on the green transition requires considering different aspects of issues such as home-to-work commuting, mobility, overall energy use, and occupational profiles and understanding the potential trade-offs that may hinder or nullify the desired effects. Eco-design of digital decarbonisation supports the UN SDG 7, 9, 12, 13.

Achieving workplace decarbonisation and mobility climate targets requires the involvement of employers and employees and a combination of different measures. It is not enough for employers to take new initiatives or introduce new employee benefits; companies must change employee behaviour and ensure the active involvement of their employees.

Acknowledgement

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Optimization of Powertrain of Hybrid Electric Vehicle Using Power Split Device

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Abstract

Hybrid Electric Vehicles (HEVs) represent a significant development in the automotive industry integrating Internal Combustion Engines (ICE) with electric propulsion systems to reduce carbon footprints. A power split device (PSD) enhances overall system efficiency of HEVs, and enables effective recuperation of energy through its dynamic control of power allocation and ability to capture and store energy during deceleration. This paper optimizes the powertrain of an HEV using PSD, and creates an Energy Management Strategy (EMS). Urban Dynamometer Driving Schedule (UDDS) is used as input in coordination with efficiency maps of engine and motor to determine optimal gear ratio (between k =2.8 to 3.6) to fulfil flexible torque request of the vehicle, traffic efficiency and reduced fuel consumption. A mathematical model is built incorporating engine, motor, battery, and transmission system and vehicle dynamics. The optimal gear ratio of planetary gear set is obtained which resulted in a 12% improvement in overall system efficiency compared to conventional settings. Additionally, the analysis revealed a peak torque output of 265 Nm at 1,500 - 4,500 RPM, affirming that the optimized powertrain effectively fulfils dynamic torque requirements. The methodology used in this research can be used for future design of HEV powertrains to increase energy efficiency.

Keywords*: power split device, hybrid electric vehicle, powertrain, optimization*

Introduction

The world is facing an increasingly pressing challenge of climate change mostly caused by Greenhouse Gas (GHG) emissions from conventional automobiles. Using Hybrid Electric Vehicles (HEVs) is a crucial step in addressing environmental sustainability and energy efficiency in the transportation sector. The interaction of conventional engines, electric motors, and energy storage is coordinated by the HEV's powertrain. HEVs are specifically designed so that an electric motor and an Internal Combustion Engine (ICE) provide the necessary power for operation, with the addition of a battery or other secondary electrical energy storage sources (M. Sabri, Danapalasingam & Rahmat 2016). Because of the extra power source's flexibility, drivers can choose between an ICE and an electricity storage system to suit their needs, which results in higher fuel efficiency. The electric power supply is typically employed for low-speed driving and stop-and-go operations, which increases the efficiency of the HEV powertrain by over 40 %.

Three main categories can be used to categorize HEV setups that are available in the vehicle market to satisfy driving needs and efficiency goals (Minaker 2019). The first one is mild hybrid configuration. It gives the gasoline engine a little boost instead of using energy exclusively for electric propulsion, notably when accelerating from a complete stop. It aids in relieving the gasoline engine's additional power requirement for the air conditioning system. The second one is full hybrid configuration**.** Full hybrid vehicles have an electrical component in addition to a petrol engine, just like mild hybrids. However, compared to a mild

hybrid, its electrical system is capable of handling a higher workload. In reality, the majority of full hybrids can travel a certain distance using only electric power. Full hybrid vehicles can be further categorized into parallel hybrid and series hybrid. In a parallel hybrid configuration, the engine can be powered straight by the engine, straight by the electrical motor, or simultaneously by both systems. With a series hybrid, the gasoline engine powers the electric motor, which functions as a generator, and the electric motor powers the wheels alone. The wheels are never propelled by the gasoline engine. As hybrid technology has advanced, some vehicles—known as 'seriesparallel' hybrids—function as a combination of the two types, with the on-board computer system determining the most efficient one to run at any given moment. Full hybrids use both regenerative braking and the energy from its gasoline engine to charge their battery system, much like mild hybrid systems do. The third one is plug-in hybrid configuration. Plug-in Hybrid Electric Vehicles (PHEVs) have the ability to recharge their batteries through both internal and external chargers. They typically have longer electric-only ranges than complete hybrids. They basically act as a transitional type between fully electric and fully hybrid cars. The fourth one is Electric Vehicle (EV) with range extender. These hybrid range extenders use a gasoline engine to operate the electric motor or charge the battery. A power split device (PSD) can be used to increase overall system efficiency of HEVs. This paper aims to optimize the powertrain of an HEV using PSD, and creates an Energy Management Strategy (EMS).

Literature Review

Power split device (PSD) is the main part of the power-split powertrain system and is mainly responsible for dispersing the engine's power output in HEVs. It works by channelling some of the engine's power by an electric path to power the vehicle's battery while it is in motion, while the remaining amount is directed through a mechanical path to propel the vehicle directly (Wang *et al.,* 2014). A key benefit of this dual capability is that it allows the PSD to effectively control engine speed and torque without being influenced by the vehicle's speed or the external road load. This makes it easier to run an engine and keeps it operating within its high-efficiency operating range by enabling continuous variable speed control (Li & Kar, 2011).

The American Hybrid System (AHS) provided by General Motors (GM) and the Toyota Hybrid System (THS) created by Toyota are the two well-known and well-established power-split systems currently being used in the automobile industry (Liu & Peng, 2010). These systems incorporate PSDs, showcasing their established efficacy in the field of hybrid car technology. PSDs use smooth engine and electric motor coupling and uncoupling, which greatly improves the vehicle's overall performance and efficiency. Two motors and two planetary gear sets are used in a compound power-split configuration, as seen in **Figure 1**, to control power distribution inside the system. Motor 1 (M1) connects to Planetary Gear Set 1 (PS1), whilst the engine and Motor 2 (M2) connect with Planetary Gear Set 2 (PS2). Brake (B) is Clutch (C) is positioned between the rings of PS1 and PS2, whereas the ground is situated across the rings of PS1 and PS2. Through C and both gear sets' carriers, the two planetary gear sets, PS1 and PS2, are joined. The motors, PS1, and PS2 functions are combined in this compound power-split setup to create a single PSD (Bellman & Dreyfus, 1958).

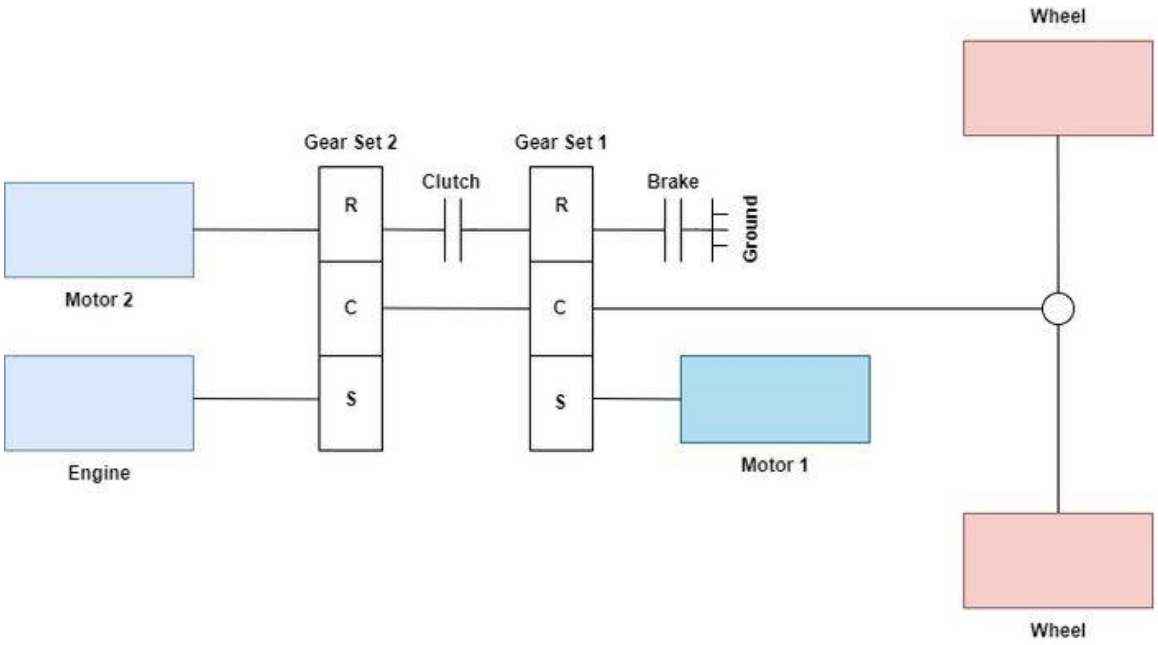

Figure 1: Compound power split configuration

In real-world scenarios like plug-in hybrid city buses, the compound power-split configuration of this type functions in several modes. Motor 1 is able to propel the car directly while it is in Electric Vehicle (EV) mode since the clutch is released and the brake is engaged. During power-split operation, power from the engine can now be transferred to the wheels through both mechanical and electrical channels since the clutch is engaged and the brake is released (Guo *et al.,* 2021). Motor 2 acts as a generator in the electrical path, feeding Motor 1 with power. In the meantime, the PS2 and PS1 ring gears and carrier facilitate the direct transfer of engine power to the wheels in the mechanical path. Except for the fact that Motor 2 serves as a traction motor and Motor 1 serves as the generation motor, the clutch conditions in the power recirculation mode are identical to those in the power-split mode. Notably, when the powerrecirculation mode is engaged, energy conversion occurs in the electrical path. Power loss is significant, and system efficiency is declining (Rios-Torres, Liu & Khattak, 2019).

This study discusses the use of a PSD to increase a hybrid electric vehicle's efficiency. PSD technology is incorporated into HEV systems, which is different from previous research. It examines a parallel HEV's fuel usage. MATLAB Simulink is used to create the simulation model for this investigation, making use of the vehicle modelling and simulation toolboxes provided by the software. In order to find the ideal gear ratio for the car, this paper also calculates the cost of gasoline and electricity and compares it with the gear ratio. The Kia Sorrento Hybrid has been chosen as the model car for this study in order to investigate hybrid powertrain optimization. Table 1 provides its technical specifications. By adjusting to different driving situations, Sorrento's efficient PSD effectively controls the power distribution between the electric motor and internal combustion engine.

Table 1: Overall technical specification

Vehicle		
Vehicle Mass	**Coefficient of Aerodynamic drag**	**Height (F.W.D)**
1898 kg	0.32	66.7 inch
Height (A.W.D)	**Frontal Area**	**Wheel base**
8.2 inch	2.32-2.51 m^2	110.8 inch
Engine		
Max Power	**Max Torque**	**Max Speed**
132 kw @ 5,500 rpm	265 Nm @ 1,500-4,500 rpm	
Motor		
Rated Power	**Rated Torque**	**Max Speed**
50 KW	265 Nm	120 km/h
Battery		
Voltage	**Capacity**	**Energy**
270 v	6 Ah	1 kwh

Methodology

To conduct this research, initially, a research of the literature is done to determine specifics such as the angle between the maximum vehicle performance plane and the characteristic speed plane (Chmelicek *et al.,* 2019). Then mathematical modelling and simulation are done in MATLAB Simulink to determine range of gear ratio, number of gears in sun, ring and carrier. Finally, running cost analysis is done on the basis of mass of fuel consumed and electricity charge and the total cost to operate the vehicle. Several HEV parameters, including the engine, battery, motor/generator, PSD, and vehicle dynamics are modelled mathematically. In order to calculate the running cost for the PSD, the initial gear ratio is analysed by updating the mathematical model, and the planetary gear assembly condition is determined.

Results and Discussion

Mathematical Modelling

Engine modelling

During a lengthy driving cycle, to aid in the calculations, torque is provided as a function of engine speeds and the mass of fuel injected every cycle using a lookup table. For the modeling, the engine dynamics are disregarded. As a point of comparison, the 132kW/265Nm maximum engine power of the Kia Sorento is used.

The fuel consumption is evaluated by (Ogata, 2009):

$$m_f = \frac{T_{ic} * \omega_{ic}}{\eta_{ic} * H_L}$$

Where, m_f is mass of fuel injection, T_{ic} is torque of ICE, ω_{ic} is R.P.M, η_{ic} is the efficiency of ICE and H_L is the lower heating value.

Motor/Generator modelling

The efficiency data from the KIA Sorento is the foundation for the electric motor/generator (MG)'s features. The efficiency of the motor/generator is determined by torque and speed, where η = f(T, ω). The battery's electricity is transmitted to the MG when it uses it. The power consumed can be expressed as follows (Negoro & Purwadi, 2013):

$$PMG = TMG * \frac{\omega MG}{\eta MG}$$

The generated power is represented as:

$$PMG = TMG * \omega MG * \eta MG$$

When, the generator generates electrical energy, i.e., when power flows from the motor/generator to the battery pack.

Battery modelling

The battery model is represented by an equivalent circuit with an internal resistance as shown in Figure 2.

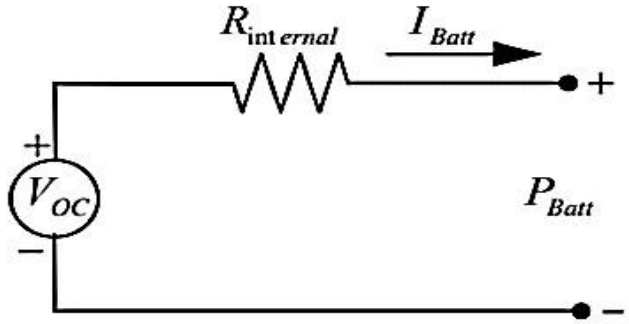

Figure 2: Battery electrical equivalent circuit

Figure 2 illustrates a corresponding circuit with an internal resistance that serves as a representation of the battery concept. The function that determines the battery output power is V_{oc}, I_b, and R_{int}, and is represented by:

$$Pb = Voc * Ib - I2b * Rint$$

PSD modelling

The planetary gear set is the main component of the power split transmission. The engine is connected to the carrier, the generator to the sun gear, the motor to the ring gear and final driveline, and the sun gear, carrier, and pinion gears that make up the planetary gear set. The following is the fundamental ratio of a planetary gear (Janulevičius & Giedra 2008):

$$\frac{\omega_s - \omega_c}{\omega_r - \omega_c} = -\frac{Rr}{Rs} = -k$$

Where, ω_s is the R.P.M of Sun Gear, ω_c is the R.P.M of carrier and ω_r is the R.P.M of the ring.

Vehicle dynamic modelling

The automobile stores the mechanical energy produced by the propulsion system. The amount of mechanical energy required to drive the vehicle is influenced by rolling friction losses, aerodynamic friction losses, and uphill driving losses. The basic equation for the vehicle model is (Ren, Crolla & Wheatley 2007):

$$F_r = f_r * m * g * \cos\alpha$$

PSD Gear Ratio Analysis

Initial gear ratio determination

Determining the initial gear ratio. The speed function of planetary gear elements can be expressed mathematically using the PSD model (Minaker 2019):

$$\omega_s + k\,\omega_r = (1 + k)\omega_c$$

A key component of the analysis known as the Characteristic Speed Plane (CSP) in the Cartesian coordinate system, where the rotational speeds ω_r, ω_c, and ω_s correspond to the x, y, and z-axes, respectively, is the mathematical representation shown above. The planetary gear system's operational limits are clearly demonstrated by the CSP. Figure 3 illustrates how plane A, which has discrete segments, represents the CSP. When the sun gear is running at its maximum speed, A_1A_2 represents the speed connection between the carrier and the ring gear and lies in plane abcd, which is parallel to the xy-plane. A_2A_3 represents the speed relationship between the ring and sun gears at maximum carrier gear speed. It is located in plane bcgf, which is parallel to the xz-plane. Finally, A_3A_4 occupies plane cdgh, which is parallel to the yz-plane and displays the carrier and sun gear's speed relationship when the ring gear runs at its maximum velocity.

The plane B is introduced corresponding to ωs = ωs, max. It is worth noting that plane A is -2 the conditions when ωr = ωr, max, ωc = ωc, max and associated with a normal vector u= [k, -(k+1), 1], while plane B is characterized by a normal vector v = (_____ _____^{2} ,, ^{1}). These geometric representations serve as ωr, max ωc, max ωr, max fundamental tools in the analysis, providing critical insights into the behavior and limits of the planetary gear system under various operating conditions (Liu & Peng, 2008).

A larger range of speed regulation on the engine and motor is necessary for the planetary gear ratio to work properly. This implies that the vehicle's performance will be better the smaller the angle between planes A and B. One can compute the angle between planes A and B (Zhang *et al.,* 2020).

$$\theta(A, B) = \cos^{-1}\frac{\vec{u} \cdot \vec{v}}{|\vec{u}|\,|\vec{v}|}$$

The angle curve between planes A and B with the planetary gear ratio is found to be 0.03 radians based on a review of the research (Zou *et al.,* 2020). After modelling, the ideal gear ratio is then determined to be between k = 2.8 and 3.6.

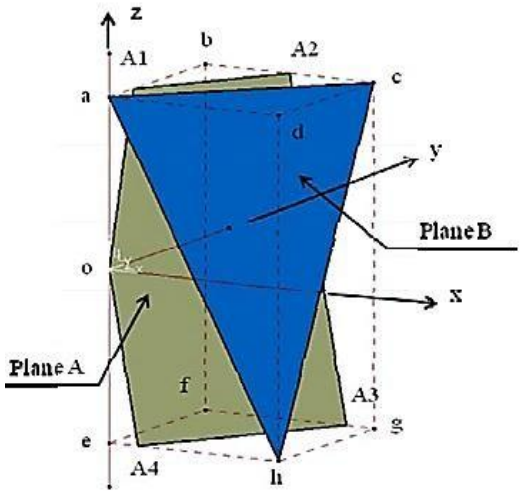

Figure 3: Relationship between characteristic speed planes with maximum vehicle performance

Planetary gear condition of assembly

The intended gear ratio determines the planetary gear train teeth numbers to use in the context of assembly concerns. This design method provides a foundation for determining the tooth number because it assumes that the ring gear will remain stationary. This arrangement places the sun gear in the driving gear position and the carrier in the driven component position. As a result, the following formula (Cao, He & Wei 2021) can be used to determine the exact gear ratio between the solar gear and the carrier "i":

$$i = 1 + k$$

The relationship between the tooth number of the planetary gear train (N_s, N_r, and N_c) is:

$$N_c = \frac{N_r - N_s}{2} \qquad \frac{i - 1}{2} = N_s$$

Based on the condition of assembly:

$$\frac{(N_r + N_s)}{n} = C$$

Combining the above equation:

$$N_s: N_c: N_r: C = 1 : \frac{(i-1)}{2} : (i-1) : \frac{i}{n}$$

Table 2 shows tooth number which meets the condition of assembly for different gear ratios.

Table 2: The Tooth Number which meets the condition of assembly from gear ratio 2.8 to 3.6

k	C	Ns	Nr	Nc
2.8	24	22	50	18
3	20	14	46	16
3.2	25	20	56	20
3.4	24	20	52	18
3.6	28	24	62	22

Running Cost Analysis

The Urban Dynamometer Driving Schedule (UDDS) driving cycle utilized in the simulation is depicted in Figure 4 (Mozaffari *et al.* 2016). Based on the simulation of optimal control, 3.2 was determined to be the ideal gear ratio. Table 3 displays the fuel consumption, running costs, and ultimate SOC at various gear ratios (2.8 to 3.6) at the UDDS driving cycle.

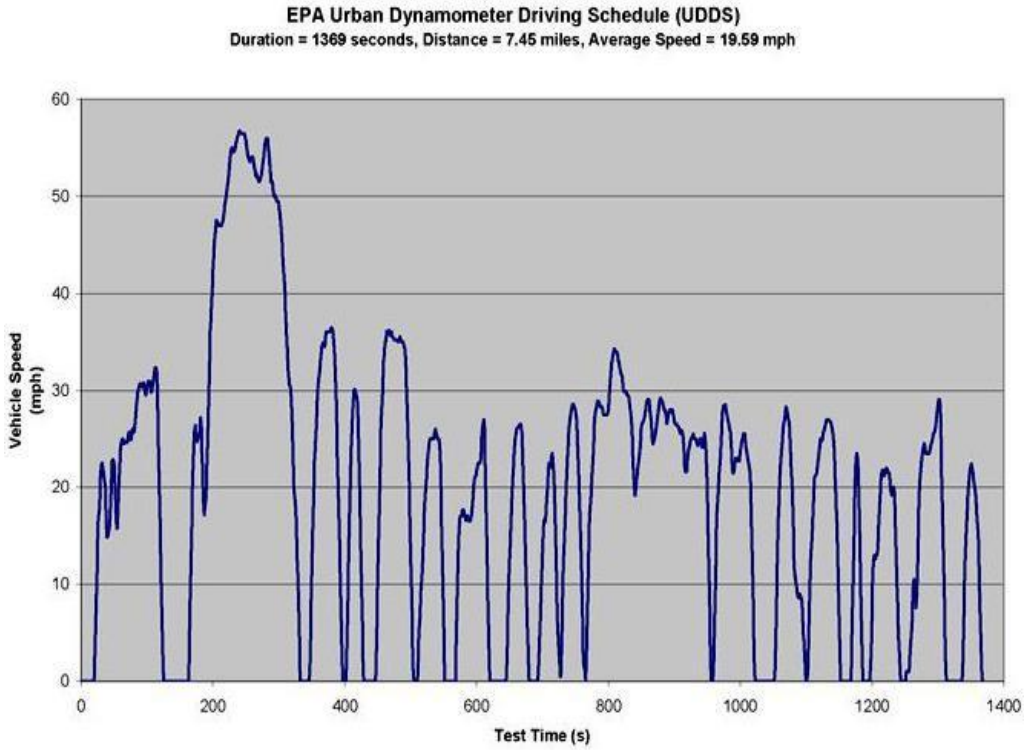

Figure 4: EPA UDDS Cycle

When comparing the table to the other gear ratios, the cost of operation is lowest at k = 3.2, but the mass of gasoline utilized is lowest at 3.6. The battery's initial State of Charge (SOC) was 0.9. After the UDDS driving cycle, it was found that the final SOC dropped in direct proportion to the gear ratio increase.

$$\eta = T_c * \omega_c = \frac{\frac{T_r * \omega_r}{[\frac{1 - k \quad \omega_r \quad \eta_{MG} \quad \eta_c^k}{1 + k * \omega_c}]} \quad \frac{1}{\eta_{MG}^k \eta_{*\sum k * \sum kc}}}$$

The efficiency of power transfer from the planetary gear's output shaft to the engine's input shaft shows a declining trend as the planetary gear ratio drops, which should be taken into consideration while choosing the exact engine and motor/generators for the system (Zhao *et al.,* 2020).

There is an increase in the amount of electricity that is transmitted from the engine to the generator. Because it entails two separate energy conversion processes converting mechanical power to electric power and then turning electric power back into mechanical power, this phenomenon is significant.

Because of power losses that arise from both energy conversions, this dual conversion mechanism has a lower overall efficiency (Jian *et al.,* 2011). To put it in simple terms, more power flowing from the engine to the generator means that there will be an equal and higher loss of energy during these subsequent power conversions, which will reduce transmission efficiency.

The power sent from the engine to the generator decreases as the planetary gear ratio rises. As a result, there must be a higher demand for electricity from the battery to the drive motor in order to meet the needs of the vehicle's driving wheels. The battery's State of Charge (SOC) rapidly decreases as a result of this increase in demand (Cipek *et al.,* 2020). When the SOC drops below the threshold, the engine must produce more power in order to keep the SOC at a predetermined level. This is very important to maintain a sufficient SOC level. The overall efficiency of the transmission system decreases as a result of this collection of scenarios.

Table 3: Comparing the Running cost and fuel Consumption at Different Ratios

K	Fuel Consumption [gm]	Gasoline Cost [Nrs]	SOC	Electric Cost [Nrs]	Total Cost [Nrs]
2.8	79.4281	19.642	0.4382	153.933	173.576
3	77.423	19.146	0.449	150.974	170.120
3.2	75.156	18.586	0.468	145.768	164.354
3.4	76.8642	19.008	0.4571	148.755	167.763
3.6	75.12	18.577	0.455	149.330	167.907

Figure 5 depicts the cost analysis result in the bar chart below.

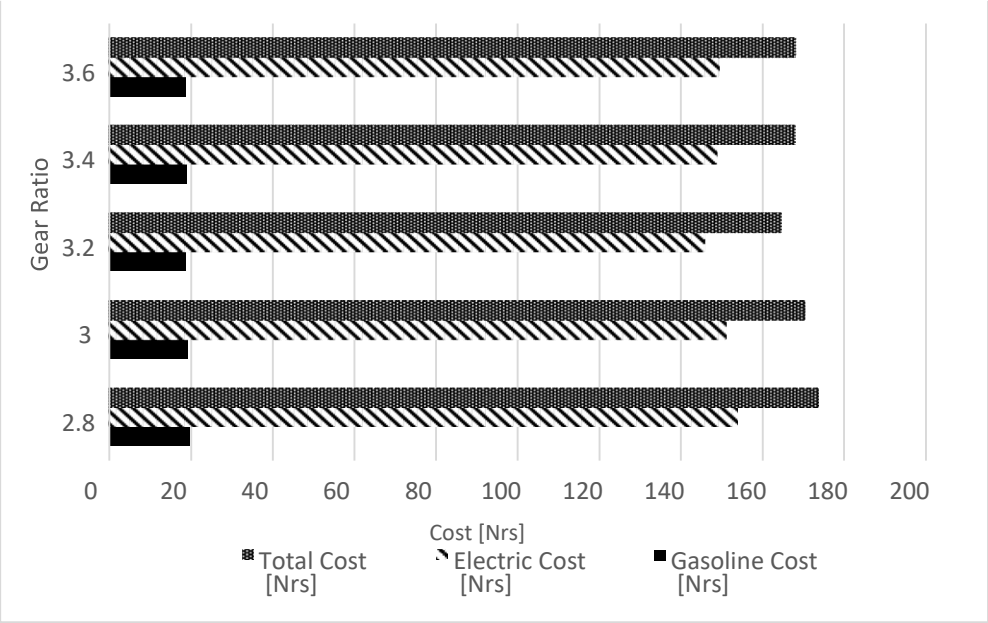

Figure 5: Cost Analysis Graph

Conclusion

The impact of PSD on its gear ratio and fuel efficiency has not been well studied in the literature to date; it has only covered HEV and Energy Management Strategies. In order to maximize the planetary gear ratio, an innovative PSD design is presented in this research study. The UDDS cycle is used to achieve an optimal planetary gear ratio through control simulation. This study also looks into the wider effects of different PSD planetary gear ratios on the performance of the powertrain and the cost of operating the vehicle. The results highlight the usefulness of gear ratio as a powerful tool for PSD design, demonstrating its capacity to maintain and even improve vehicle performance in addition to reducing operational expenses.

Acknowledgement

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Revisiting the Method of Service System Map: Operational Logic and Rules of Use

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Abstract

Service system diagram, as an important tool for service design, can help describe system relationships thus assist subsequent service design planning. However, existing studies have problems such as vague conceptual definitions, unstructured operational processes, and unclear instructions for use. The motivation of this study is to sort out and optimize the conceptual definition, operation process logic, and usage rule description of the service system diagram. This paper clarifies the connotation of the service system diagram through literature review and theoretical investigation, tightens the logic of procedure steps, provides the instructions for usage rules, and verifies the optimized method through the case study of "Shenzhou Pregnant Mothers' Special Car". The optimized service system diagram concepts, and help service designers to improve the clarity, definition and rigor of the system's operational processes and elemental relationships.

Introduction

Over the past decades, industrial production has gradually evolved from mass consumption to personalized and localized models (Morelli, 2009), and in a fiercely competitive business environment, traditional product solutions are no longer effective, and companies are paying more and more attention to enhancing the value of their products through services (Vasantha *et al.*, 2012), and service design has begun to receive wider and wider attention. In the field of service design, designers need new tools to analyze and design service systems and develop service solutions (Morelli, 2009), and methods and tools to assist service design have begun to emerge one after another. Among them, service system map has been widely used as a tool to assist the analysis, synthesis, and reconstruction of complex information in the service design process (Jiang & Zhang, 2017).

With the research and exploration in academia and industry, service system map has become an important tool to assist service design, as a visualization method, it can represent the material and non-material features of service production in a clear and unambiguous way, which facilitates designers to design in a system context and communicate and collab-orate with all parties (Morelli, 2004). Service system map is not only able to represent the relationship between things in service production, but also facilitates the understanding of how the system is organized (Jun & Lee, 2004). However, the current research re-lated to service system diagrams still suffers from the problems of vague concepts and non-specific operational procedures, which leads to the lack of complete and reasonable knowledge of the designers in the process of using the system diagrams, ignoring its system generalization function, and failing to accurately understand the specific operational re-quirements in this tool (Jiang & Zhang, 2017).

Therefore, this paper aims to re-examine and redefine the existing service system map concepts and operational procedures, in the second chapter through the method of literature review to sort out the current status of the research and shortcomings of the service system map, on this basis in the third

chapter to re-propose the operational logic and steps of the service system map to improve the service system map in the use of the process of the practical difficulties of the problem, and in the fourth chapter to the In Chapter 4, the case study of "Shenzhou Pregnant Mothers' Special Car" is analyzed, further elaborating the pro-cess of the operation procedure, which provides support for designers to better consider the service solutions in the context of the system.

Literature Reviews of Service System Map

Conceptual Evolution of Service System Map

Originally derived from software development tools, system map was introduced in 1979 as a systematic approach to quality management tools in the QC development department of the Japan Science and Technology Consortium (JSTC). Jégou, Manzini and Meroni (2004) introduced it as one of the tools of the Design Plan portfolio in the field of service design, a collaborative problem-solving oriented approach to the design process, whose use incorporates visual graphical foundations, defines the flow of information about the elements, aims at designing a service strategy, and assists the participants in expressing and communicating relevant service concepts. Morelli and Tollestrup (2007) proposed a three-category approach to product-service systems from a systems perspective for addressing the challenges of the new paradigm shift in industrial production. The concept of system map is reflected in several places in the text, among which System Platforms (SP) is one of the most representative graphical tools for aggregating different players (e.G, service providers, manufacturers, institutional players, and end-users) and describing the capabilities of each one of them, structuring their interactions in material and immaterial flows, and facilitating the production process in a cooperation (Morelli and Tollestrup, 2007). After 2 years, Morelli further refined the design process and tools for service design, complementing the methods of pro-filing actors, Design Orienting Scenarios, and solution platforms, which can be used to man-age material, information and financial flows, specify the logical sequence of interactions between participants, and represent the front and back office of a service in a system perspective.

Jun and Lee (2011) explain that the key to grasping a system is to explicitly represent the relationships between elements and to understand the organisational principles of the system, and propose four modes of thinking that distinguish between various types of rela-tionships:

- System as a law that binds components together (hierarchical).
- Systems as rules that guide practice (problematic).
- Systems as functions that support the possibility of user action (availability).
- The system as a condition that facilitates transcendental ideas (symbolic).

Forlizzi J (2013) proposed a framework for product-service ecology, using system map as a methodology to help designers to view situations holistically, for describing and understanding the dynamic relationships between people, products, social activities, and the environment that surrounds the system, as well as for guiding the production of solutions. Subsequently, the Polytechnic di Milano introduced it as a library of service design tools (www.servicedesigntools.org) to describe all the entities, flows and relationships in an ecosystem, i.e., to clearly show all the key players that have an impact on the users, the organization, and the service chain, as well as the types of value exchanges between all of them. Vezzoli *et al.* (2014), in Designing for Sustainable Service Systems, applied the concept of system map to

the five phases of Strategy Analysis, Exploring Opportunities, Conceptual Design, Architecture Design, and Communication in a modular approach to system design to assist in presenting the requirements for building the system in stages. Wang (2015) called his system diagram as Service ECO-system map or System Paradigm Diagram (ERAF System Diagram), as one of the important means of service proposal stressing the system diagram's role in the representation of information flow, financial flow, material flow, and behavioural interactions among system elements. The ERAF System Diagram is one of the most important tools for service proposals. And the four key elements of ERAF (Entities, Relations, Attributes, and Flows) are proposed for the representation of characteristics, purposes, elements, and structures in the system diagram. Chen (2016) viewed System Map (SMP) as a visual descriptive tool of the service system, encompassing service objects and relationships between them, as well as the flow of materials, experiences, money, and information.

In summary, service system map was initially proposed to improve the process approach in service solutions by emphasizing visual graphics, flow relationships between elements (material, information, and financial flows), and assisting participants in communicating expression and collaboration. As the field of service design has evolved, the meaning of service system diagrams has been continuously enriched. Existing scholars have focused on the overall control role of the service system map, the key players in the service and the types of value exchanges between the players, and the visual description of the relationships between the elements (entities, relationships, features, flows).

Operation procedures of service system map

Bijker (1978) proposes methods of discovering actors, the first through a 'snowball' cascade process, firstly, identifying key groups and participants in service development. Secondly, interviews were conducted to identify new groups that might be relevant. Finally, the pro-cess continues until no new groups are added. The steps of the second are like the first, ex-cept that the interview process is replaced with a theoretical analysis of the major groups and communities. Morelli and Tollestrup (2007) organized the process of using the existing systematic ap-proach in a sequence of analysis phase, design, and development phases of service design. The specific process was to understand the possible interactions, motivations, and expecta-tions between participants by drawing ACTOR NETWORK MAPPING, MOTIVATION MATRIX, and to examine the time series in the service and describe the capabilities and interactions of the different participants through the IDEF0 methodology and the systemic platform methodology (material flow and non-material flows). The 4 steps of constructing a system map are described on the Service Design Tool Library website (www.servicedesigntools.org):

- Identify all the players and entities involved in the supply and delivery of the service.
- Place the user at the Centre and other stakeholders around, after which the links between the various players and elements are constructed.
- Observe the map and add the missing parts of the map.

Highlight pain points or gaps on the map. Chen (2016) divided the specific practice of service system mapping into 4 steps:

- Identify system elements and write them on sticky notes or cards.
- Categories the system elements under different system functions to generate sub-systems.
- Establish relationships between subsystems, define relationships between system elements, and establish a system structure.

- Generate a service system map. And the importance of designing the relationship between system elements was emphasized.

Jiang (2018) proposed a method for applying system map in the stages of problem discovery, solution creativity and solution presentation. The specific operational steps are as follows:

- **Problem discovery phase (5 tasks):** exhausting elements-conducting brain-storming, attribute merging-aggregation posting and definition posting, build-ing hierarchies-categorization posting and linking, rapid evaluation-labelling, insight opportunity -Insight and Description.
- **Solution Concept Phase (4 tasks):** Idea Gathering - Stakeholder Analysis, Con-cept Organization - Comparison and Integration, Organizational Relationships - Positioning the Inner and Outer Rings, and Objective Evaluation - Matrix Scoring.
- **Solution Presentation phase (3 tasks):** creating characters-folding and draw-ing, interpreting situations-arranging them one by one; reviewing and evaluat-ing-describing the process.

Hu Fei (2019) proposed a 6-step process for using service system diagrams: Planning-identify workshop participants.

- Grouping-group participants into groups
- Creating initial stakeholder diagrams
- Presenting and comparing-each group presents and compares system map.
- Discussing and merging -Merge the systematic maps.
- Follow-up-Conduct follow-up interviews with participants.

Stickendorn *et al.* (2018) categorized system maps into three parts: stakeholder maps, value network maps and ecosystem maps, and demonstrated the roles and linkages of the three system maps.

Through a comprehensive comparative analysis of the methodological processes of using existing service system maps, as shown in Table 1, it was found that the use of service system maps contains 3 main phases, i.e., discovering the stakeholder phase, constructing the relational flow phase, and discovering the insights phase. In the existing research, the use of all stages of the process is accounted for is the service design tool library website and the use of the methodological process proposed by Ying Jiang.

Table 1. Process of using service system diagram.

S.N.	Stage	Specific Method	Source
01	Stakeholder discovery phase	The first through a 'snowball' cascade process, firstly, identifying key groups and participants in service development. Secondly, interviews were conducted to identify new groups that might be relevant. Finally, the process continues until no new groups are added. The steps of the second are like the first, except that the interview process is replaced with a theoretical analysis of the major groups and communities.	Bijker *et al.* (1987)
		understand the possible interactions, motivations, and expectations between participants by drawing Actor Network Mapping, Motivation Matrix.	Morelli (2007)
		Identify all the players and entities involved in the supply and delivery of the service.	www.servicedesigntools.org

		Identify system elements and write them on sticky notes or cards.	Chen (2016)
		Problem discovery phase: exhausting elementsconducting brainstorming. Solution Concept Phase: Idea Gathering - Stakeholder Analysis. Solution Presentation phase: creating charactersfolding and drawing.	Jiang (2018)
		Planning-identify workshop participants.	Hu (2019)
		Creating stakeholder maps	Stickendorn *et al.* (2018)
02	Constructing Relationship Flow Stage	Examine the time series in the service and describe the capabilities and interactions of the different participants through the IDEF0 methodology and the systemic platform methodology (material flow and non-material flows).	Morelli (2007)
		Place the user at the centre and other stakeholders around, after which the links between the various players and elements are constructed. Observe the map and add the missing parts of the map.	www.servicedesigntools.org
		Categories the system elements under different system functions to generate sub-systems. Establish relationships between subsystems, define relationships between system elements, and establish a system structure. Generate a service system map.	Chen (2016)
		Problem discovery phase: building hierarchiescategorization posting and linking, rapid evaluation-labelling. Solution Concept Phase: Concept Organization - Comparison and Integration, Organizational Relationships - Positioning the Inner and Outer Rings. Solution Presentation phase: interpreting situations-arranging them one by one.	Jiang (2018)
		Grouping-group participants into groups Creating initial stakeholder diagrams Presenting and comparing-each group presents and compares system map.	Hu (2019)
		Discussing and merging -Merge the systematic maps. Follow-up-Conduct follow-up interviews with participants.	
		Creating value network maps and ecosystem maps.	Stickendorn *et al.* (2018)
03	Discovering Insights Stage	Highlight pain points or gaps on the map.	www.servicedesigntools.org
		Problem discovery phase: rapid evaluationlabelling, insight opportunity -Insight and Description. Solution Concept Phase: Objective Evaluation - Matrix Scoring. Solution Presentation phase: reviewing and evaluating-describing the process.	Jiang (2018)

Existing gaps in the research on the use of service system map

After the service system diagram was introduced into the field of service design, its concepts and uses have been discussed to a certain extent, but a unified consensus on the definition has not been formed.

In terms of the use process, relevant research is still relatively scarce, and the existing use of the methodological process also suffers from the lack of clarity and completeness of the process phases, and the description of the implementation methodology is general and rough.

Bijker's proposed methodology for discovering actors provides a good theoretical reference for identifying stakeholders, but the methodology is too broad and lacks project-specific relevance. Morelli describes the methodology used in the analysis phase, the design and the development phases of service design, but does not give a specific implementable operational process. The Service Design Tool website gives a more specific process for service system diagrams, but still does not indicate the operational details of each step. The steps for using system diagrams proposed by Chen focus on the establishment of structural relationships between systems and sub-systems but are not further elaborated in relation to specific scenarios. Jiang tries to refine the steps of using system diagrams from more specific operational stages but focuses on the methodological innovations of service system diagrams in different stages, without exploring the specific details and implementation methods of each implementation step, for example, how to find stakeholders, how to classify and analyze stakeholders, and how to construct the flow of relationships between elements are not given as references. The specific methods are not given. Hu's methodology for using service system diagrams points out how to develop a system diagram in the form of a workshop, but also lacks specific methods for operational tasks. This is service design doing suggests that multiple diagrams are needed to represent a system diagram but does not mention the specific steps to produce them.

Therefore, this study focuses on the problem of unclear stage process and unspecific step description in the process of using service system map, and through the method of literature review and theoretical sorting, it proposes the logic of using service system map and the specific process, which is convenient for service designers to understand the tool and use it operationally.

Operational logic and process steps for reconstructing service system map

Through the literature review, this paper has identified the purpose, characteristics, and key elements in the conceptual definition of service system map, which provides the basic elements and key points for the process steps of using system map. In terms of specific implementation procedures, this study is based on the three phases of the existing service system map implementation process, namely the "stakeholder discovery phase, the relationship flow phase, and the insight discovery phase" for further refinement. In terms of specific implementation procedures, this study is based on the three phases of the existing service system map implementation process, namely the "stakeholder discovery phase, the relationship flow phase, and the insight discovery phase" for further refinement. To specify the methodology for each stage, the "Consensus Journey" stage was added before the "Stakeholder Discovery Stage" as a methodological process for finding stakeholders. The goal of the "Discovering Insights" stage is to improve the existing service system and develop a new service strategy, so this study optimizes the "Discovering Insights" stage as the "Exporting Service Strategy" stage. Therefore, this study optimizes the "discovering insights" stage into the "outputting service strategies" stage. The four stages of the service system map are:

- Consensus journey.
- Clarify the stakeholder hierarchy.

- Construct the relationship flow.
- Output service strategy.

At the same time, this study provides specific and detailed step-by-step instructions for the operation of each stage, which improves the ambiguous meaning and unclear operation of the previous system diagram. The specific use logic and operation process are as follows:

- Applicable audience: designers (service designers), engineers, managers (product managers)
- Timing of application: strategic analysis, exploring opportunities, conceptual design, architectural design, communication.
- Purpose of Use: Used to assist designers in understanding and discovering the user experience (customer journey), to express the flow of information, money, logistics, and behavioral interactions between elements, types of interactions, and to test the feasibility of the system, the importance of relationships, and the frequency of interactions, to express the system dynamics on which the service system depends for its existence, i.e., the purposeful behaviors, the structure, and the flow of relationships between the various service elements in the system;. It is also an important tool for describing the current state of the service, solving problems, and identifying proposals for service implementation.
- Number of Participants: depends on the size of the population to be analyzed, ideally taking into account the number of stakeholders involved.
- Equipment: paper, pens, post-it notes, computer, etc.
- Time required: Ensuring the integrity of the task, stopping when all participants have no further amendments to make to the content of the service system diagram (usually 1 to 2 hours).

Procedural Steps:

Step 1 Consensus Journey. Identify customer/user activities (user journeys) and develop consensus.

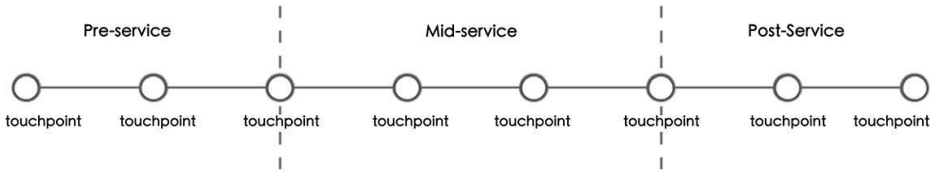

Figure 1. Mapping the consensus user journey

Finding stakeholders is an important part of the service system map implementation process, but the original methodology either does not give a specific method to find all stakeholders, or expands the scope of stakeholders too much, but is less targeted to specific projects or situations. In this paper, we propose to use the consensus (user) journey as the starting point for finding stakeholders, and reason out all stakeholders through the touchpoints in the user journey, as shown in Figure 1.

Step 2 Clarify the stakeholder hierarchy.

Finding stakeholders based on customer journeys starts with finding the first level (core stakeholders) service providers (service providers) that customers encounter, then finding the second level (direct stakeholders) service providers behind them through these stakeholders, and finally finding the third level (indirect stakeholders) service providers supported behind them through the second level stakeholders, as shown in Figure 2.

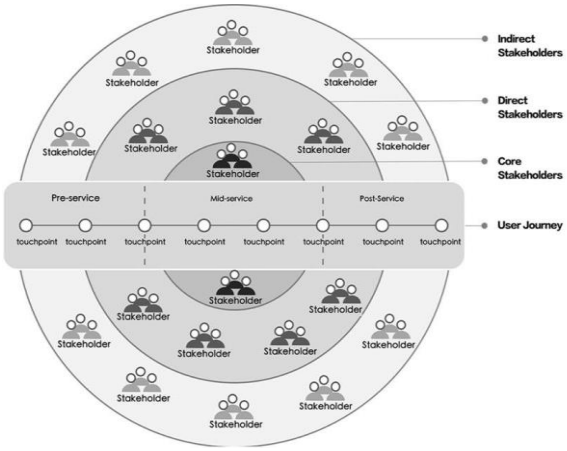

Figure 2. Clarify the stakeholder hierarchy map

Step 3 Construct a relationship flow.

Mapping the three main flows of links between elements in turn, it is recommended that the information flow be sorted out first (transmission of information), then the material flow (transmission of products or services), and finally the financial flow (circulation of money), and that after each of these flows a test be carried out to ensure that the flow of the relationship is complete, logical, and rigorous, in order to build a system of their interactions, as shown in Figure 3.

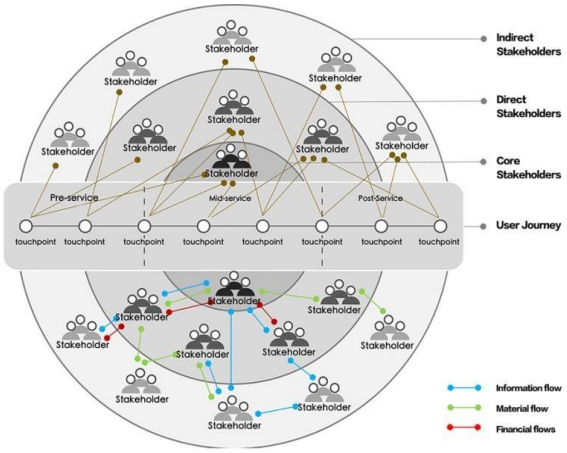

Figure 3. Mapping the three main flow relationships of links between elements

The fastest way to express the reference: (using tools: different colored sticky notes, colored pens, whiteboard/paper) Use yellow sticky notes to paste the flow on the whiteboard/paper, and then use the lines to sort out the relationship between the flow; use blue sticky notes to express the flow of information, paste it in the middle of the connecting lines; use green sticky notes to express the flow of material, paste it in the customer or equipment provider; use red sticky notes to express the flow of funds, paste it in the customer; finally, separate the knotted lines (it is recommended that you draw on the whiteboard, when too much or overlap, you can always erase and redraw); finally, make the knot line to

separate (it is recommended to draw on the whiteboard, when the line is too much or overlap, you can always wipe off to redraw); finally, make the line to separate. Finally, separate the knotted lines (it is recommended to draw them on the whiteboard, so that when there are too many lines or overlaps, they can be erased and redrawn at any time).

Step 4 Output service strategy.

Based on the constructed relational flows, the original system network built from a single flow is reexamined, and the flows are merged, simplified (reduced) or split to optimize the relational flows to form an upgraded version (version 2.0-3.0) of the service strategy, which is named, as shown in Figure 4.

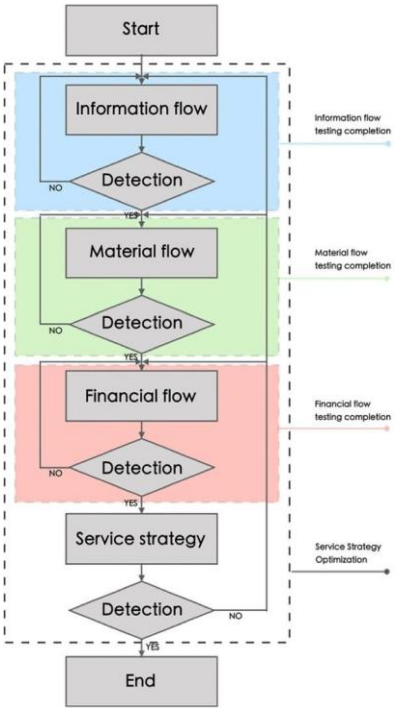

Figure 4. Relationship Flow Detection Wireframe Flowchart

Cautions

1 ***Graphics.*** The use of standardized, concrete, and visual elemental graphics as the basis for building service scenarios, transforming abstract concepts into more concrete and clear graphical contexts (service scenarios) through elemental restructuring to assist designers' understanding and expression.

2 ***Relationship flow.*** The service system map needs to be tested after each flow is constructed to ensure a clear and effective, potential, complete and reasonable flow of relationships between service elements, to define or construct a new service system.

3 ***Service Strategy.*** Aiming at the complex relationship between the three major flows composed of service elements, optimize the configuration, reorganization, reduction or increase of the flow to propose a holistic, reasonable, and sustainable innovative, iterative, and upgraded service solution.

4 ***Service Concept.*** The service strategy proposed in the new service system diagram needs to be named as a service concept, so that it can be clearly recognized by any uninformed person who receives it,

as well as effectively communicated, co-created, and discussed in a collaborative manner, to ensure its effectiveness.

Case Application Analysis of Service System Map Using Processes: An Example of Shenzhou Pregnant Mothers' Special Buses

Shenzhou Special Car is a comprehensive travel application platform that combines self-driving, special car and carpooling services, using the human-vehicle ecosystem it has constructed to provide users with high-end taxi services, with vehicles readily available. Shenzhou Pregnant Mothers Special Car is a service on the platform that pays special attention to the travelling needs of pregnant women, providing professional drivers and vehicles to ensure safe and comfortable travel for pregnant women. The service aims to promote the progress of the car industry, and to encourage society to care more about the travel safety of pregnant women and promote safe driving. This paper is based on the existing service system of "Shenzhou Pregnant Mothers Special Car", and analyses and improves the strategy of this system with the newly proposed service system diagram operation logic and usage procedures.

Step 1 Consensus journey: Identify the Pregnant Mums Ride activity (user journey) and develop a consensus journey.

Pregnant mothers are the core stakeholders in this system. Firstly, the journey of pregnant mothers is sorted out in five service stages before, during and after the service, i.e., order-taking stage, waiting stage, welcome stage, travelling stage, and farewell stage. Secondly, the behaviors and touchpoints of pregnant mother passengers in each stage are listed. Third, based on the touchpoints, the stakeholders that are directly related to the touchpoints in the journey of the pregnant mother are derived. Fourthly, the indirect stakeholders are deduced from the direct stakeholders, and then the user journey is mapped, and the stakeholders are found, as shown in Figure 5.

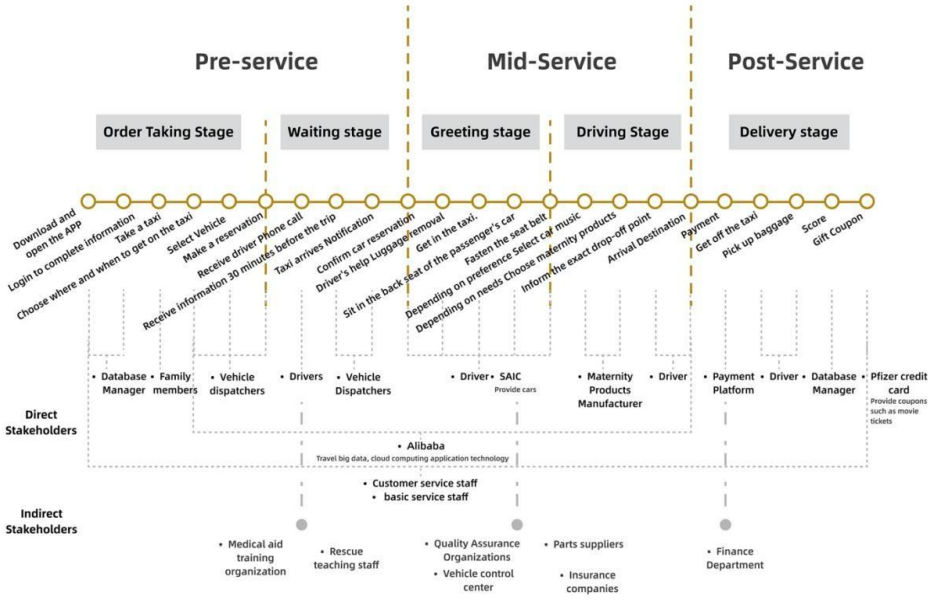

Figure 5. Shenzhou Pregnant Mothers' Car Consensus Journey Map

Step 2 Clarify the Shenzhou Pregnant Mums' Ride stakeholder hierarchy.

The stakeholders found in the consensus journey are arranged in concentric circles, which clearly shows the three levels of stakeholders, i.e., core stakeholders, direct stakeholders, and indirect stakeholders, and is further reviewed and supplemented. In the case of "Shenzhou Pregnant Mothers' Car", as shown in Figure 6, the core stakeholder is the pregnant mothers' passengers, and the direct stakeholders are family members, maternity product manufacturers, payment platforms, basic service teams, vehicle dispatchers, Alibaba, database managers, customer service personnel, SAIC Group, car drivers, and Pudong Development Credit Card. Indirect stakeholders are rescue teaching staff, medical aid training organizations, car manufacturers, DMV, parts suppliers, insurance companies, and quality inspection organizations.

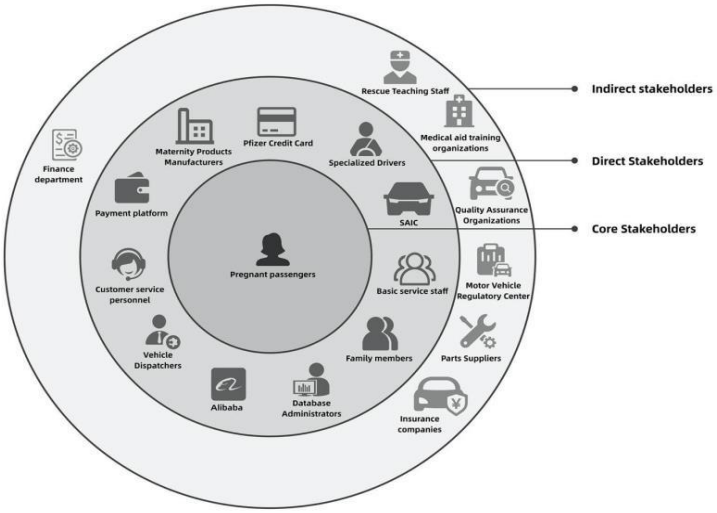

Figure 6. Shenzhou Pregnant Mums Special Car Stakeholder Hierarchy Map.

Step 3 Construct the relationship flow of Shenzhou Pregnant Mothers' Ride.

The relationship flow is constructed for three levels of stakeholders, as shown in Figure 7. Firstly, the information flow is sorted out, in this case, the information flow is mainly the communication between pregnant mothers and their family members who help them to take a taxi, the information exchange between the car drivers and pregnant mothers, the information management and support provided by the basic service team and the database managers to the pregnant mothers, the consulting and help exchange between the customer service staff and the pregnant mothers, as well as the big data information provided by Alibaba to the vehicle scheduler and the database manager Support. Second, the material flow is sorted out. The material flow in the case of "Shenzhou Pregnant Mothers' Special Car" mainly consists of pregnant women's products manufacturers providing pregnant mothers with vomit bags, fetal education CD-ROMs and other pregnant women's products, Pudong Development Credit Card providing coupons to pregnant mothers, SAIC Group providing cars to drivers, and rescue and teaching personnel and medical aid training institutes providing rescue teaching to drivers, quality inspection institutes, vehicle control bureaus, and medical aid training institutes. Quality inspection organizations, DMVs, parts suppliers, and insurance companies provide vehicle management, maintenance, quality

inspection and insurance services to SAIC. Finally, there is the sorting out of the flow of funds, which in the case mainly consists of the payment of fees by the pregnant mother to the payment platform, which transfers the funds to the finance department.

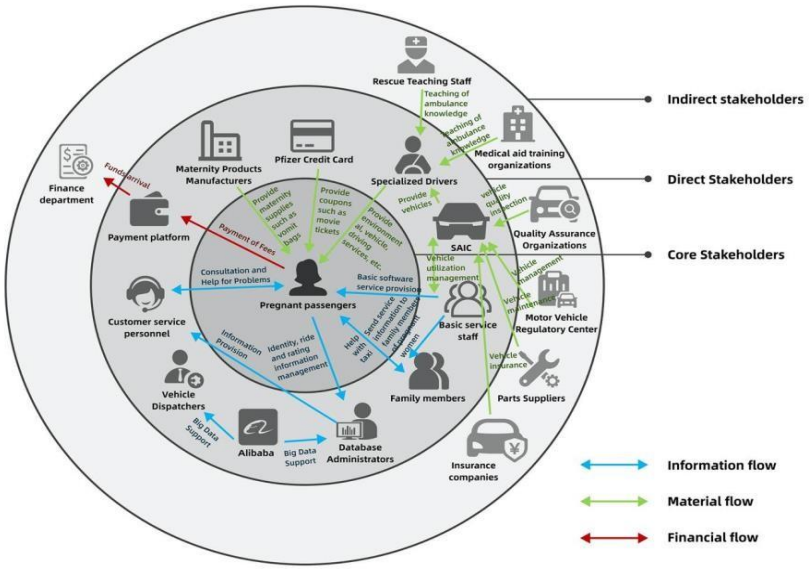

Figure 7. Shenzhou Pregnant Mothers Special Car Service System Map

Step 4 Output corresponding service strategy.

The relationships constructed in the third step were reviewed to confirm, supplement, merge or split the single relational streams, and the order of detection was information flow, material flow, and financial flow, to optimize the existing system relationships to form an upgraded version of the service strategy and to name it, as shown in Figure 8. After reviewing, in the information flow, the relationship flow that Shenzhou Shuttle transmits information about pregnant women's rides to their families is missing. In the material flow, the relationship flow of vehicle usage management between Shenzhou Shuttle and SAIC is missing.

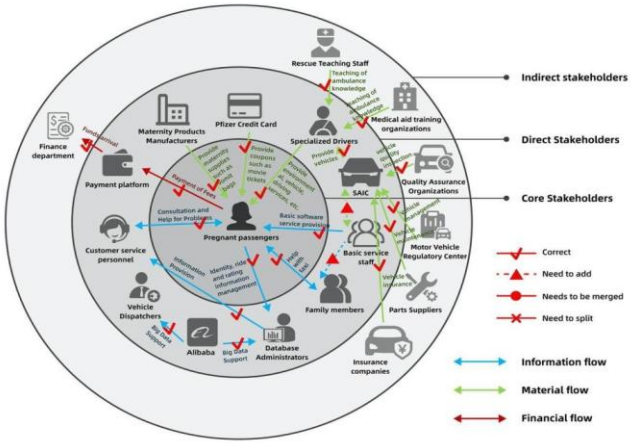

Figure 8. Shenzhou Pregnant Mothers Special Service System Map Inspection Chart

The relational flow was optimized to form a new system diagram, and insights and service strategies to enhance the existing service were found, as shown in Figure 9. Firstly, in terms of information flow, the information communication between the pregnant women's families and the basic service side of Shenzhou Chauffeur should be increased, so that the pregnant women's families can understand the real-time situation of the pregnant women in the process of travelling in the car, and the peace of mind of the pregnant women's families can be increased, to enhance the user's sense of trust. In terms of material flow, the collaborative communication between Shenzhou Chauffeur's basic service department and SAIC should be increased. Since the vehicles of Shenzhou Chauffeur's service are provided by SAIC, and the maintenance, quality inspection, insurance and management of the vehicles are all undertaken by SAIC, Shenzhou Chauffeur needs to strengthen the management of the vehicle information to ensure the standard and quality of the vehicles.

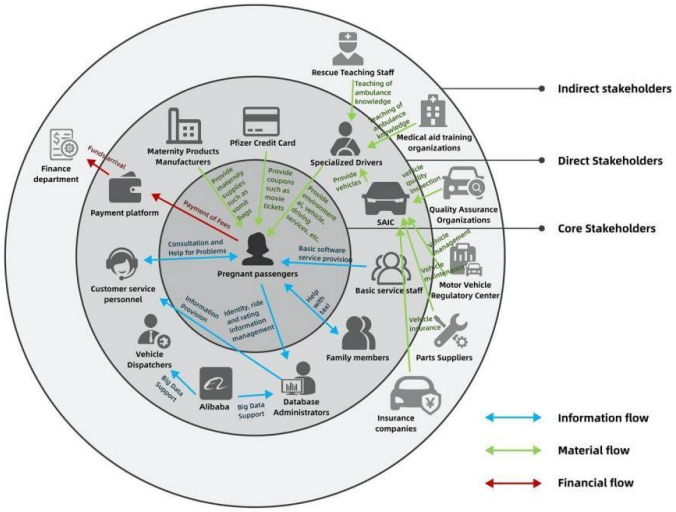

Figure 9. Shenzhou Pregnant Mothers Service System Map Optimized Version

Discussion and Conclusions

Service System Map is an important methodological tool for developing systematic solutions in a system-oriented context, but the design discipline has not yet formed a unified, comprehensive, and specific process steps for its use. This paper proposes a set of service system map operation logic and usage rules through literature review and theoretical sorting, which helps designers to describe the system situation more clearly and accurately, discover the irrationality of the existing system relationship, and form an optimized version of the service strategy.

After reorganizing and defining the concept of service system map and the process of using it, this paper concludes with a more operational conceptual definition of Service System Map, i.e., Service System Map is a visual descriptive tool based on a consensus of the user journey that has already been formed for the purpose of depicting or creating a flow relationship between service objects and the objects' material, financial, informational, and interactional relationships, which can be used to both It can be used both to develop and improve existing user journeys and to plan for the implementation of user journeys, thus demonstrating their value for the improvement of the overall service system.

Compared to other system mapping tools, system mapping focuses on showing the flow of material, financial and information elements between primary and secondary actors within a system, often organized in the form of a 'holistic' mindset and graphical framework, which assists designers in developing a concrete viewpoint from conceptualization to service construction and makes the process of system operation more intuitive. It also allows for a more intuitive presentation of the system's operation: it is clear at what point's users interact with the system, which actors need to be involved in the system's operation, and how money and materials are organized and managed.

The field of service design is still consolidating its methodologies and tools and changing and adapting them to different contextual conditions. In future research, new case studies and further application of rules will provide improved support for the optimization of the operational logic and rules of use of service system map.

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The Unsustainability of 'Sustainable' Architecture: Externalization of Socio-Environmental Impacts

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Abstract

This work presents some reflections from doctoral research, which has investigated the relationship between Society and Nature, especially conflictual in the field of Civil Construction – the one in which Architecture is practiced. Observing the environmental inadequacy of hegemonic architectural production, this article seeks to understand the reasons that could explain why our category has distanced itself from the accumulated knowledge in 'sustainable' construction practices. By reconstructing the historical path that led us to the environmental incompatibility of buildings in the present, we conclude that the modern architecture that has prevailed to date easily conforms to the unsustainable hegemonic mode of production. Modern 'green' buildings also consume significant amounts of energy and material resources. Therefore, one aspect that hides the alleged eco-efficiency of 'sustainable' buildings refers to the externalization of socio-environmental damages. As a consequence, we conclude that the so-called 'sustainable' architectural strategies only produce a palliative effect, since their production processes depend on exploiting natural elements and workers (on and off construction sites) and are insufficient to contain the dangerous changes we have promoted in the world's climate system.

Introduction

This paper discusses some results of a doctoral research that had investigated our contemporary and historical relationship with Nature – as a human species, in general, and as architects and urban planners, in particular. This relationship has caused profound socio-environmental imbalances, to the point that we are considered responsible for the beginning of a new geological era: the Anthropocene (Marques, 2022; Latour, 2020). We are witnessing a critical moment in the history of humanity, in which the modification almost to the extreme of the elementary balances of the Earth system has put life at risk of extinction – in its human form, but also in that of thousands of other species that inhabit this planet with us (Marques, 2015; Ângelo, 2016; IPPC, 2021). Even in the unlikely absence of new pandemics (such as Covid-19, whose effects we are still dealing with), the world we occupy, from now on and if we do not immediately change our ways of being here, will become progressively sick – hotter and more climatically unstable, polluted and intoxicated, biologically impoverished and socioeconomically dysfunctional (Marques, 2020).

To a greater or lesser extent, all human activities have an impact on the environment. This is especially true for the field of action of architects and urban planners: the buildings and cities we have built not only physically alter the earth's surface, interrupting vital flows, but also extract their material and energy sources to the limit, returning them in the form of waste that destabilizes ecosystems (Saramago, 2023). In other words, we are largely responsible for the configuration of the current scenario of "world exhaustion" (Araóz, 2020, p. 193). On the other hand, considering that we have changed the planet since we appeared on Earth, why has the relationship between human beings and Nature been pointed out as dangerous and disastrous only in more recent periods?

We can find clues to answer these questions by analyzing how the consolidation, expansion and spread of the capitalist mode of production took place on a world scale. It is possible to say that, at least since

the middle of the eighteenth century, with the birth of its industrial version, we have fostered the not obscure desire for infinite growth. The 'reasonableness' of our metabolic relationship with Nature, until then in constant modification to meet human needs with a certain parsimony, was replaced by the 'thirst' for hypertrophied accumulation of wealth, satiated only with the (supposedly unlimited) 'domination' of the biophysical world (Latouche, 2011). In other words, the relationship we have established with the natural environment in recent centuries necessarily envolves the “contradictory unity between capital and Nature” (Harvey, 2016).

At the global level, since the Rio de Janeiro Conference, promoted by the United Nations (UN) in 1992, our political representatives have supported the 'way out' of the environmental problem by the 'greening' of capitalism – and we, architects, by the 'greening' of buildings and their infrastructures: insisting, at the time, on the notion of sustainable development. This 'exit' has spread to practically all economic sectors, including the one that supports the area of Architecture and Urbanism. In the preparatory document for Eco 92, also known as the Brundtland Report, the definition that would become hegemonic of sustainable development already appears, that is: that development that meets the needs of the present, without compromising the ability of future generations to meet their own needs (UN, 1987).

This formulation tried to harmonize the desired growth of national economies with meeting social demands and the attention to the biophysical limits of the planet. To this end, as a central idea, it proposed to 'modernize' the productive forces, fostering the improvement of products and equipment (as well as construction systems and buildings) that are more economical in terms of energy. The “ecological modernization”, which guides the conception of sustainable development – as well as the idea of sustainable architecture resulting from it – adheres, therefore, to the economic logic, conferring on the markets, eventually regulated by the States, the function of dealing with environmental degradation. In other words, according to this conception, to achieve sustainability, it would be enough to 'save' the environment, investing in technologies and systems considered 'clean' (Acselrad, 2002).

However, what we argue here is our inability to solve the socio-environmental problems generated by the thermofossil civilization of the Anthropocene simply with practices based on the notions of sustainable development and sustainable architecture. After all, despite all the growing warnings from the scientific community regarding the need to quickly change our practices and that have been reiterated in world events on the environment – promoted by the UN since the concept of sustainable development was first coined – we continue to produce cities and build the planet through processes that, instead of moving us away, bring us closer and closer to socio-environmental crises. Therefore, the current definition of sustainability must be placed under critical lens in the analysis of the material production of the space in which we live.

To achieve the goals of the research, we have taken the following steps:

Reviewing and discussing publications that correlate Architecture, Civil Construction, sustainability and climate emergency; Mapping and analyzing the main socio-environmental impacts of Civil Construction, Critical reconstructing the historical path that led us to the environmental incompatibility of buildings in the present; Systematization of research results.

Through a vast review of the literature, we initially point out the damage caused by human activities in general, which has led to the configuration of the three ecological crises, threatening to life on Earth:

climate change, loss of biodiversity and widespread chemical pollution. We also indicate the environmental impacts specifically derived from the activities of Civil Construction, in which the area of Architecture and Urbanism is inserted. To this end, we list the negative changes in the natural environment by phase of the production chain of this sector (from the extraction of raw materials to the dismantling of buildings).

Observing the environmental inadequacy of hegemonic architectural production, we seek to understand the reasons that explain the distancing of our category from the knowledge accumulated in 'sustainable' construction practices. After all, as a rule, traditional constructions are deeply connected to the socio-environmental and cultural context of the territories in which they are settled. Then how to understand the abandonment of this long constructive tradition in favor of an internationalized production, disconnected from the natural environment? In order to answer this question, we rely on the arguments of Sérgio Ferro and David Harvey, in order to critically reconstruct the historical path that led us to the environmental incompatibility of buildings in the present. Through logical argumentation, we also emphasize the importance of the spatial dimension (and, therefore, of the built environment) for the expansion and continuity of the unsustainable capitalist dynamics.

Finally, the last phase of the research synthesizes the analyses carried out throughout the work, reenforcing the thesis of the unsustainability of sustainable architecture. This paper focusses on the last steps of the research.

Literature Review

Revisiting de theory of Sérgio Ferro and other authors, like David Harvey, we conclude that the 'modern architecture of oil' that has prevailed to date easily conforms to the unsustainable hegemonic mode of production, especially because it favors the logic of expropriation of labor, associated with the overexploitation of natural resources. In his critical historiography of architecture, Sérgio Ferro indicated that civil construction, because it is organized as manufacturing[1], constitutes one of the main sources of the "primitive" accumulation of capital. Indeed, the construction of defensive walls and sumptuous cathedrals in the emerging medieval cities, between the ninth and eleventh centuries, effectively contributed to securing and accumulating large sums of circulating value. Although these typologies were not created with simply economic objectives, they constituted an important locus for a seminal, accentuated accumulation of capital. If, in origin, the economic activities involved in civil construction had been conducted through "developed simple cooperation"[2], practiced within the scope of medieval corporations, little by little, these processes enabled the emergence of a new manufacturing format for the organization of labor. This occurred rapidly on construction sites, preceded only by the textile sector, and has continued to characterize the organization of the construction sector until the present day (Ferro, 2021).

The second hypothesis elaborated by Sérgio Ferro concerns the fact that, also due to its manufacturing character, over time, Civil Construction has become one of the means used to face the "equalization of the general rate of profit in capitalism" (Marx, 2017). Sérgio Ferro analyzed that the manufacturing of civil construction, since it employs a huge amount of labor and little machinery, helps to provide the economy as a whole with a large part of the masses of surplus value necessary to avoid the collapse of the capitalist system. Because of this, even after the Industrial

1 Karl Mark [1867] (2017), in volume I of Capital, characterizes the different processes of production – simple cooperation, manufacturing (serial and heterogeneous) and industry

– in terms of forms of exploitation, direction, submission (formal or real) and division of labor. In relation specifically to manufacturing (see Chapter 12 – Division of labor and manufacturing), it can be characterized by the following aspects: capital concentrates almost all the means of production and there is a marked division of labor, which is only formally subordinated (therefore, technical operations still depend on the worker, unlike what occurs in mechanized and automated industry). [2] "Simple" cooperation, because there is no institutionalized division of labor, as defined by Marx. Sérgio Ferro adds the adjective "developed" to indicate the formation of the "collective worker" in this mode of work organization in Construction (Ferro, 2021).

Revolution, manufacturing production sectors, such as construction, continued to be fundamental: ultimately, replacing human labor with machines signifies losing the source of value creation. Thus, the construction sector was never fully industrialized. In order to adapt to new forms of organizing labor, innovative materials were used, which took the place of traditional techniques that underpinned the builders' know-how (Ferro, 2018). In the words of Sérgio Ferro (2006): “If the so-called millennial experience of the worker was linked to earth, stone and wood, it would lose its strength if new materials were used, without tradition”.

The definitive rupture in the autonomy of workers on construction sites, which occurred with the rise of modern architecture, also represented a rupture with the territory, the natural environment. The ‘modern architecture of oil’ that has prevailed to date, like the socioeconomic system in which it originates, is unsustainable due to its very nature. Instead of adapting to different territories and biomes, it combines with capitalist accumulation, helping to raise average profit rates through the exploitation of construction sites and nature (Saramago, 2023). We also observe that, with the help of civil construction, capital promoted, and continues to promote, the necessary “spatial adjustments” to the overaccumulation crises that are characteristic of it (Harvey, 2016). In the post-war period, for example, the United States – apart from having bet on imperialist expansion, consolidating its militaryindustrial complex – mobilized a large part of its surplus capital and labor in physical structures: by creating the suburbs; redesigning the metropolitan regions of major USA cities; and integrating the South to the West of the country, through the interstate system of highways (Harvey, 2018). In fact, one of the first suburbs in the country, built in the vicinity of New York between 1947 and 1951, offered more than 17 thousand single-family homes to the rising American middle class (Figure 1).

Figure 1. Aerial view of the suburb of Levittown, Pennsylvania (USA). Levittown Public Library Collection

In recent years, in turn, we have witnessed the rise of the Asian region, with China's internal megamodernization program constituting our most recent and intense version of “spatial-temporal adjustment” – starting to capture surpluses produced by Japan, Taiwan, and South Korea (Harvey, 2020). In fact, the significant growth in world demand for materials and construction inputs since 2000, especially cement (one of the main responsible for increasing global greenhouse gas (GHG) emissions), is largely due to China: in just 3 years (2011-2013), the country consumed 6.651 billion tons of cement, while, in comparison, the United States used 4.405 billion tons of this material during the entire twentieth century (Swanson, 2015).

From another viewpoint, while the production of the built environment enables, fosters and nourishes some type of initial capitalist development, over the years, it restricts the possibilities of accumulation, since it creates spatial barriers (Harvey, 2020). Therefore, part of the capitalist dynamic is the construction of physical landscapes and spatial relations adjusted 'to its image' at first, and later, when they become antagonistic to accumulation, they are destroyed (and, who knows, may be rebuilt again in the future). This is what David Harvey (2018) calls “creative destruction” – of course not in a positive sense. Precisely because it mobilizes so much work over long periods of time, as well as large investments, the material production of space requires some form of articulation between the State and financial capital. As a result, in the long term, the construction of landscapes ultimately reveals its speculative side, leading to the emergence of the same initial overaccumulation conditions – which, in turn, give rise to “uneven geographical developments” around the world (Harvey, 2016). Hence considering the relevance of the spatial dimension for the expansion and continuity of the 'unsustainable' capitalist logic, the need to question our praxis becomes more evident.

Results and Discussion

Ecological modernization does not solve the exhaustion of the world contrary to what the proposal for “ecological modernization” of sustainability defends since Rio 92, the means of production used by civil construction consume large amounts of material and energy, emitting more than a third of the gases responsible for global warming (UNEP, 2023). Only in 2019, we produced 100 billion tons of materials to meet the countless demands of the economic sectors, half of which was made up of minerals, cement, sand, clay and gravel (widely used in the construction sector). In addition, 40% of this material was intended exclusively to erect buildings. During this same period, this represented 13.5 billion tons (or 22.3%) of greenhouse gas (GHG) emissions (Circle Economy, 2023). In the case of steel, worldwide, more than 50% of this input is used in buildings and urban infrastructure works (World Steel Association, 2020), while, in Brazil, 41.2% of steel consumption occurred in civil construction in 2020 (Instituto Aço Brasil, 2020). Globally, the construction sector – which includes, it is important to insist, architectural and urban production – would also be responsible for between 12 and 16% of drinking water consumption (CIB, 2002) and 35% of primary energy use (IEA, 2020). This means that, even when said to be 'sustainable', the buildings and cities we create destabilize the natural flows on which we depend to survive.

In addition, due to the depletion of traditional deposits, input extraction techniques have currently focused on the exploitation of deposits with less raw materials – which require greater energy consumption and generate more waste. Therefore, they depend on technologically intensive methods, whose socio-environmental damage is profound (Trocate and Coelho, 2020). For example, in the case of steel production, in view of the exhaustion of deposits rich in mineral concentration, large-scale industrial

exploration has enabled the profitability of operations. To this end, it even makes use of highly toxic chemical compounds for mineral purification, resulting in a significant amount of hazardous waste (Acosta, 2016). This is especially significant when we accept the task of listing and analyzing the specific damage generated by Civil Construction, since reconfigurations of the mining sector also seek to keep up with the growing demands related to the production of the built environment – which has been eager for high-tech materials and components, such as steel.

In addition, although Civil Construction has a significant participation in the deepening of the "world exhaustion" (Aráoz, 2020), due to the 'hypersegmentation' and the worldwide spread of its production chain, there is an immeasurable sum of data on the construction sector that makes it difficult (not to say impossible) to carry out a global assessment of the environmental impacts it originates. To take the example of steel, we recall that ores are part of global production networks, whose extraction, processing, distribution and consumption operations, although globally interconnected, are geographically dispersed (Trocate and Coelho, 2020). Thus, while we extract large quantities of iron ore in Brazil and export crude steel around the world, we often import back the metal profiles that we use to erect our buildings. In this process, countless workers and agents are involved – causing impacts in each phase of this dispersed production chain. As this occurs with almost all construction inputs, we can have an idea of the difficulty in mapping the environmental consequences of the activities of our sector.

Faced with this reality, what remains for us is to perceive the centrality of the material production of space (and, therefore, of Civil Construction) in the economy as a whole, as a privileged locus of capitalist accumulation (Ferro 2006; Ferro, 2018; Ferro, 2021) – as we have argued above.

Furthermore, on this point, we think it is important to emphasize that there is a structural disconnect in our field of activity. In the same way that the capitalist mode of production, for the benefit of capital itself, specializes and fragments social labor, we can say that it also promotes the geographical dispersion of the production processes of Civil Construction. This ends up diluting our category's understanding of how the inputs and components we use for the materialization of buildings and cities have been extracted and manufactured, harming the natural environment in different ways. The great difficulty in mapping the global impacts of Civil Construction, therefore, is not an effect, but the raison d'être of the very process of transforming raw materials into commodities, or 'natural capital'. Meanwhile, we continue to use 'concrete-steel-glass' without having the real dimension of the socioenvironmental damage generated by the hegemonic solutions of architectural production. In other words, it almost goes unnoticed that the transformation of the natural environment into a built environment corresponds, literally, to the dismantling of the planet (Saramago, 2023).

Externalization of socio-environmental impacts

The environmental concern in our area, in general, is centered on evaluating whether certain construction systems and/or buildings rationally use natural resources. This also explains the rapid development of the processes for verifying the environmental performance of buildings since the 1990s, or the "green seals". Alongside architects and urban planners, political leaders, economists and thinkers from different fields of knowledge continue to bet on the eco-efficiency of 'green' technologies to continue economic growth rates, without supposedly compromising planetary boundaries. In short, according to this group and

reverberating the consensus of sustainable development of Rio 92, it would be enough to use technology in the 'correct' way to solve any environmental problem.

However, technological innovations are capable of generating only relative gains, since, due to the growth, in absolute terms, of economic activities, populations and their consumption levels, even with such innovations, we continue to generate more and more impacts and emissions (Veiga and Issberner, 2012, 2012). The 'exemplary' performance data presented by certain countries and regions, therefore, are based on their internal activities, equated according to the precepts of a 'green economy', disregarding the outsourcing of those with high environmental impact. If environmental impacts, as well as carbon emissions, were accounted for in the countries where the final consumption occurred (and not in the emitting countries), the results of these indicators would be quite different (Veiga and Issberner, 2012). As Horacio Aráoz (2016) also reminds us, it would be a "gross argumentative fallacy" to consider the Brazilian economy as extractive (due to the high rates of bauxite exports, for example) and the German economy as non-extractive (because, since 1987, no deposit has been explored there), given that the German country consumes the largest amount of aluminum per capita in the world (produced from the ore that leaves Brazil – Figure 2).

Figure 2. Landscape resulting from the extraction of minerals in Carajás (PA, Brazil).
Google Earth (2024)

Therefore, when evaluating the eco-efficiency of products and buildings, we need to consider the entire production chain involved. If we do not do so, we will be contributing to the perpetuation of a devastating "imperial way of life" through a "selective ecological modernization" (Brand and Wissen, 2021). In fact, the profound degradation of the natural world and communities, in the current context, has occurred especially in countries that have rich deposits of lithium[3] and rare earths – coveted elements for the manufacture of equipment and composition of cutting-edge systems. This occurs even in the specific field of Architecture and Urbanism, where 'green' construction solutions – which employ high technology and

have been promoted in all parts of the world as the right path to sustainable architecture (strongly encouraged by certification processes) – such as steel, cobalt, lithium and rare- earth elements. Therefore, they continue to exert pressure on the environment, even in regions that are still in a state of preservation. [3] One example is Chile. With the increase in demand for this lithium, the country, which already suffers from water scarcity, tends to go through even more severe supply crises. Cf. IQBAL, Yanis. "As devastações da extração de lítio no Chile", IELA, 20 Jul. 2020 (em rede).

Even with the increasing alerts from the scientific community regarding the socio-environmental collapse with which we are surrounded (IPCC, 2021), the standard response from our particular area, regarding the socio-environmental problems, has been a kind of 'technical fix' – consolidated by different environmental performance standards, such as LEED and BREAM. Hence, what it is generally considered as 'sustainable' architectural production involves the use of accessory elements added to buildings, such as special glass and filters, solar collectors and photovoltaic panels, wind turbines and automated shutters. The architectural typologies of these buildings are not questioned, nor the means and the processes used in their creation. Therefore, the so-called 'sustainable' construction strategies only produce a palliative effect, since their production processes depend on exploiting natural elements and workers (on and off construction sites) and are insufficient to contain the dangerous changes we have promoted in the functioning of the "climate machine", as expressed by Claudio Angelo (2016). In short, constructing more buildings, whether 'sustainable' or not, implies generating more damage and more GHG emissions.

It is also important to recognize that the segmentation of the civil construction production chain, as well as the historical separation between design and construction site (Ferro, 2006; Ferro, 2018; Ferro, 2021), compels us to focus our attention almost exclusively on its products. Even when our research efforts go beyond the form and plasticity of the architectural symbols we design, the environmental concern in our area usually focuses on assessing whether certain construction systems or buildings rationally employ natural resources, especially energy. Thus, the ecological benefits attributed to new systems and components that aim to reduce the environmental impacts of buildings 'camouflage' the "ecological costs of their production" (Brand and Wissen, 2021). Even assuming that all buildings are supplied with renewable sources – and, therefore, when in use, could be considered more 'sustainable' as they do not emit GHG –, this reasoning does not apply to the energy and materials used in their production. 'Green' buildings continue to require the extraction of countless metals (used in the manufacture of photovoltaic panels and wind turbines, for example), which are mined using fossil fuels. In this way, alongside the "material requirements of energy transition", we should consider the "energy requirements of material transition" (Brand and Wissen, 2021). Otherwise, we will contribute to the perpetuation of the same extractive model in an 'ecologically modernized' version, which shifts socio-environmental costs to other fields, such as those holding lithium and rare earth deposits.

Conclusion

Every transformation of the natural environment into a built environment results in impacts and, therefore, damage to Nature. This has been happening since we started to build our shelters on Earth. However, the negative consequences that we have pointed out have been exacerbated in recent decades, leading us to the perception of an imminent picture of socio-environmental collapse. As we have argued,

the environmental problematic of the Anthropocene has generally been understood only in relation to the management of natural resources, in which collective action, mediated by the State(s), eventually becomes necessary to correct 'market failures'. On the other hand, according to our perception, the problem centers on the abusive appropriation of finite natural elements in order to continue capitalist accumulation. Thus, the idea that it is enough to save Nature's 'goods' and 'services' to get out of the ecological crisis in which we find ourselves, without its structural causes being really questioned and changed, is illusory.

It is worth remembering that the definitive rupture of the autonomy of workers on the construction sites, between the end of the nineteenth century and the beginning of the twentieth, also represented a rupture with the territory, with the natural environment. After all, as we said, the production processes of 'innovative' or 'modern' materials and construction components generate numerous environmental impacts (including a significant portion of global GHG emissions), while the 'concrete-steel-glass' buildings that we have been building since then, in order to maintain occupancy conditions, make abusive use of artificial conditioning systems (consuming even more fossil fuels in their operation).

For the above, we argue that the discussion of our field must prioritize the processes and means of production if we really want to change the current context. After all, the predominant architectural production, as well as the socioeconomic system in which it originates, is unsustainable by its very nature. Instead of adapting to different territories and biomes, it is an accomplice of capitalist accumulation, helping to raise average profit rates through the excessive exploitation of construction sites and natural elements. In short, there is no 'sustainable architecture' in the way we build: either we change the means and processes of production, or we will not be able to achieve some desired sustainability. If the climate emergency and the other environmental crises require urgent and systemic changes in our ways of life, they also depend on profound transformations in Civil Construction Production Chain. Thus, we insist on the need to understand architecture beyond the design of buildings, focusing on the processes and means that enable the “transformation of space through human work” (Kapp and Baltazar, 2021).

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The Intersection between MDD and DIY Aimed at Promoting Growing Materials within Established Markets

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Abstract

The sustainable use of resources is a pressing challenge for our planet, demanding attention from product designers to foster a biocentric and sustainable future. Regenerative materials, such as Growing Materials (GM), are increasingly valued for their circularity and performance benefits. To enhance collaboration between designers and innovative materials, the Material Driven Design (MDD) methodology has been developed to identify suitable markets. In addition to this, emerging regenerative materials, adaptable to the Do It Yourself (DIY) approach, are gaining popularity beyond industry, enabling work with common tools without specialized skills. This contribution proposes integrating MDD with DIY to combine theoretical research with practical verification, with the objective to validate these materials and ensure their effective application in viable markets. The process involves four MDD steps and three experimental design phases, defined by the authors, to assess Bacterial Cellulose (BC) performance in upholstered furniture. Conclusions will highlight integration opportunities and analyze associated constraints, defining a new role for designers in the GMs landscape, extending from product realization to the design of related product systems.

Introduction

Within a landscape currently dominated by a climate crisis challenging the linear design and production mechanisms established since the Third Industrial Revolution (Jiang *et al.*, 2022), the concept of sustainability is evolving within product design. It now focuses on restoration, renewal, and revitalization of the societal relationship with the integrity of nature. Design has the potential to intervene to achieve these goals through the study of various design methodologies, each emphasizing different factors such as materials, forms, object use, production technologies, or end-of-life disposal programming.

The theorization and experimentation of new methodologies underscore the importance of Regenerative Design in transcending the creation of artifacts, buildings, or human well-being. Instead, it prioritizes researching and reconstructing interconnections between these elements and the ecosystems surrounding them, emphasizing the maintenance of well-being for all involved stakeholders (Blok, 2022).

Within this framework, as asserted by Wahl (2017) and numerous other researchers and theorists, one of the emerging possibilities for the design discipline to actively address the challenge of reducing resource demand and consumption is the use of regenerative materials, specifically biological and renewable ones (Wahl, 2017). This necessitates a shift towards integrated design and production relationships with natural processes, accelerating the intersection between biology and design (Myers and Antonelli, 2019). Indeed, over the past decade, designers have begun working with new materials utilizing natural growth processes and the reproduction of living organisms, following the concept of zero-state. This concept involves

designing to restore to ecosystems the same resources used in artifact creation, thereby guiding towards a positive impact on the planet (Jussila, 2023).

Following the possibilities of Regenerative Design, this research aims to identify new possibilities for design processes that not only integrate the use of regenerative materials but also assess their harmonies and dissonances with industrial production within established markets that currently have limitations in sustainability, such as upholstered furniture (EUROPUR, 2021). The dual objective of making object production more sustainable and directing it towards the use of regenerative materials requires a new methodology that enables designers to engage in conscientious design.

It is possible to observe how in the discipline of design there has long been a desire to enhance the value of materials, stemming from the need to shorten material innovation cycles within the market (Maine et aL, 2005). This has led to a design approach that places the materiality of the object at the center for reasons of performance, sustainability, and hedonism, thereby developing design methodologies that guide designers towards MDD, such as the methodology proposed by Karana *et al.* (2015). The motivations behind the development of these methodologies are consistent with the aim to promote the use of regenerative materials within large-scale design and production, fostering a paradigm shift towards biocentric design (Santos, 2021).

However, the specific design objectives of these emerging methodologies remain valid for materialfocused design but are still not aligned with the introduction of GMs within the discipline, as they are predominantly within the industrial landscape and therefore lack considerations dictated by the intrinsic living component of Living Materials (LMs).

Therefore, this contribution aims to investigate the possibilities offered by established design procedures within the world of industrial design to promote the integration of regenerative materials. In particular, it seeks to address two main questions following a critical analysis of selected methodologies and approaches that are consistent with the proposed regenerative scenario:

- What are the points of intersection between industrialization (typical of mass production) and regenerative materials? How can they be identified and enhanced to foster a dialogue between sustainability and efficiency?
- What opportunities does the designer have within a scenario that requires a more sustainable and regenerative approach to design and production?

To achieve this goal, an analysis of selected procedures is presented along with a theorization of their integration, followed by a testing phase where the resulting protocol was applied to design a product using GM, specifically BC. Specifically, the project aims to test this methodology for designing a product aligned with principles of Regenerative Design and Sustainable Design, utilizing only natural materials, minimizing resource use, and applying Sustainable Design strategies that include closed-loop systems in the end-of-life phase. The conclusions will critically analyze the design outcome, proposing new design and methodological possibilities for a regenerative scenario and responsible design.

Literature Review

Material Driven Design: The Methodology and Objectives

To achieve the presented objectives, the research has focused on analyzing design methodologies that emphasize the development and application of materials as a central point of design. Among these methodologies, the MDD has emerged over the past decade, developed by Karana *et al.* (2015), where material analysis serves as the focal point of design, and its limitations and possibilities guide the process to identify new scenarios (Karana *et al.*, 2015).

This methodology was developed to encourage material-focused design by valuing choices regarding materials not only for what they are but also for what they do (Manzini, 1989). The entire process thus focuses on a deep understanding of the material to capture its potential applications that enhance its mechanical, performance, or aesthetic qualities. Starting with the analysis of a specific material, it is crucial to understand its composition, possibilities, limitations, production processes, and the sensory experience it offers to users (Karana *et al.*, 2015).

By combining technical characterization of the material with its experiential characterization, this initial phase includes analyzing existing material applications, with observations on the resulting sensory experiences. This latter analysis is crucial for the methodology's objectives as it can facilitate easier market acceptance (Ashby and Johnson, 2010).

The goal of the first design step is therefore a comprehensive understanding of the material, followed by the designer's ability to systematize and reinterpret the collected data, including sensory, interpretive (meanings), affective (emotions), and performative (actions, performances) aspects(Giaccardi and Karana, 2015). This enables envisioning new application possibilities for the material or enhancing existing ones. The second design phase focuses on the designer's ability to imagine how a material can contribute to functional superiority (Karana *et al.*, 2015) when integrated into a product, thus creating a Vision that relates the material itself to other products, people, and contexts.

The purpose of the Material Experience Vision requires reflecting on the research conducted in the first phase to identify potential applications that do not force functionalities and performances inconsistent with the material properties. Studies involving users and benchmarking analysis are particularly relevant in this phase, as they help identify similar materials and their relationship with users (Karana *et al.*, 2015).

Following the definition of the Material Experience Vision, the designer is tasked with identifying plausible connections between the qualities of the material in question and the created vision. The third phase focuses on constructing how and when users interact with the material according to the designer's envisioned modes in creating the Vision, and thus how material experience patterns can manifest (Giaccardi and Karana, 2015). To achieve this goal, Karana *et al.* (2015, p. 44) proposes a brainstorming session where formal material properties are defined based on selected meanings that are considered explanatory of the relational pattern being referenced (Karana *et al.*, 2015). This approach allows evaluating the appeal of a similar material during benchmarking analysis to identify adjectives that best

describe the material under review and the ensuing characteristics that conceptually strengthen its sensory attributes.

In the fourth and final step, the designer initiates the concept generation phase by synthesizing data reprocessed from the previous three phases to design an object that enhances the material according to all considerations made during the preceding steps. This phase involves making-testing actions, as subsequent prototyping and product testing are anticipated but excluded from the MDD analysis and representation schema, as depicted in Figure 1. Given the aim to design with materials that are both fully developed and still in development, concept creation and the subsequent prototyping and testing phase depend on this variable.

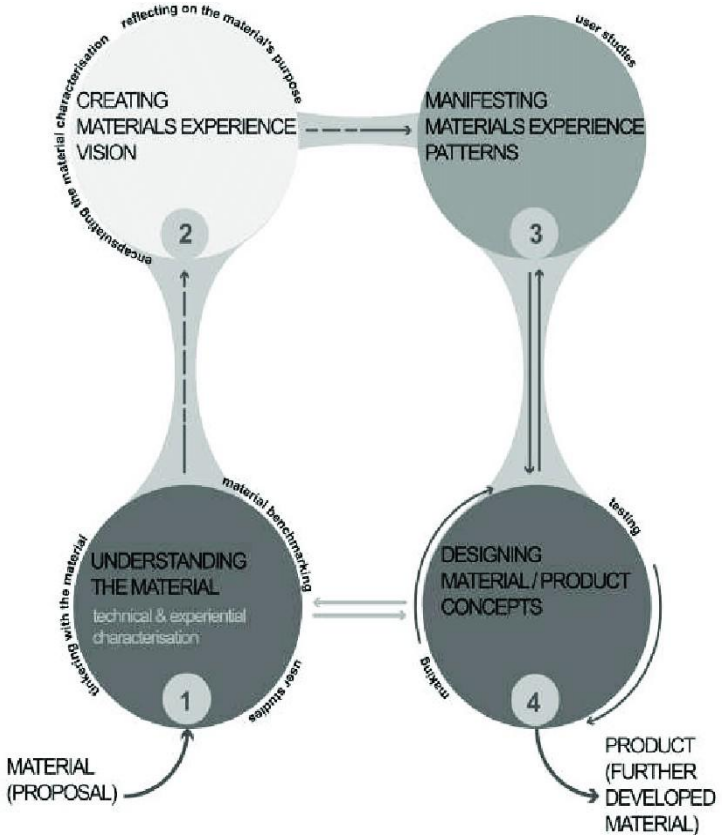

Figure 1. MDD method scheme, Karana *et al.*, 2015

The MDD methodology promotes a tangible engagement with materials, spanning from initial encounter to a comprehensive understanding of their complexities, aimed at expediting their integration into industrial production. This knowledge enables effective selection of sustainable design approaches to either slow down production cycles or close them (Bocken *et al.*, 2016), paving the way for a new ethical responsibility for designers.

The methodology schema defines specific steps allowing interaction with materials without making it obligatory. This offers designers the flexibility to choose operational levels based on the type of material, establishing a more or less tangible relationship with it. This expands the traditionally inherent possibilities of design disciplines, where material choice typically precedes object function. However, due to this dual approach, there are no vertically focused steps on tangible experimentation, crucial for processing GM. Furthermore, the intent to integrate materials into industrial processes via MDD does not fully align with the vital characterization distinguishing GM within the broader category of innovative materials, necessitating optimization of processes, re-evaluation of volumes, and production chain.

Therefore, there is a need to integrate innovative and variable processes, yet to be explored, requiring continuous practical experimentation alongside theoretical data collection, both subject to ongoing modification. For these reasons, MDD methodology proves highly intriguing for developing new scenarios where materials play a central role in responsible design, aiming for conscientious production considering the possibilities and limitations of the materials used, as well as their market influence. In the context of this research, it is essential to incorporate a segment focused on tangible experimentation to establish a new design process aimed at studying GM, respecting their intrinsic vitality and assessing scalability through critical analysis based on theoretical knowledge and practical evidence.

Do-It-Yourself: The Approach and Possibilities

Analyzing the methodological possibilities rooted in making, the DIY approach, also known as one-of, has been examined. This terminology has become popular as a fusion of craftsmanship and selfproduction (Rognoli *et al.*, 2015), driven by the desire to involve users in the design process and the demand for customization. Defined as an approach rather than a methodology due to the lack of a defined structure, the DIY approach refers to the general methods through which a particular methodology is implemented; in this case, it pertains to the inclination towards self-reliance and the availability of knowledge and means for self-management.

Initially associated with product customization, this approach is now contextualized within the realm of self-production thanks to the democratization of production technologies and the innovation spurred by open-source initiatives. Together, these developments have broadened the target audience within the making and design communities. Communities such as makers and activities in FabLabs have further solidified this product-oriented approach (Maffei and Bianchini, 2013) within large and medium-sized urban settings, supporting the circulation of ideas and the exchange of common interests, whether related to technologies, materials, or processes.

For these reasons, DIY is defined as a bottom-up approach as it encourages the democratization of material knowledge, experimentation opportunities, material processing based on learning by doing, and learning by interacting (Rognoli *et al.*, 2015).

These tangible experimental phases represent the missing element within the previously explored methodology, such as that of MDD, as well as an excellent opportunity for exploring innovative materials with constantly evolving vital components, such as GMs. This is because it focuses on direct

interaction with the material, thus including the possibility of altering results from various experiments, as well as analyzing variable parameters and equally diverse outcomes. This approach allows for a comprehensive understanding of the material not only by identifying its intrinsic possibilities but also by expanding observations to potential alterations, enabling exploration and understanding of these alterations.

To comprehend the real integration possibilities between the previously proposed methodology and the DIY approach, it is necessary to analyze the implications that the One-of world has on the field of design. Factors such as global idea exchange and local production and reproduction are closely related to industry (Gershenfeld, 2012).

In particular, the growth of the DIY culture creates an innovative scenario for the development of design processes with characteristics different from traditional ones, particularly in the close interaction between designers and production technologies. Specifically, in the case of LMs, there is a triple interaction among designers, new production technologies, and access to knowledge in the material/biological field (Maffei and Bianchini, 2013).

This sphere of action is of fundamental importance for designers, as it provides the opportunity to work with innovative regenerative materials, acquiring skills applicable within their discipline through a democratized approach that does not require specific expertise in different disciplines. This expands their own possibilities and develops integrated processes (Maffei and Bianchini, 2013).

It is also essential to understand the limitations associated with the isolated approach of DIY, primarily related to its artisanal origins. The One-of approach, when carried out independently and in isolation from other methodologies, assumes the role of a one-way exercise aimed at a single product or, as in the case of experimenting with innovative materials like GMs, a contribution to research. In the absence of a structured program, such as in the development and understanding of a new material, it would therefore be necessary to set a specific goal and establish a series of planned experiments to achieve it. This approach can lead to active participation in research but may miss the goal of contributing to reconciling design and project production with the development of regenerative materials.

Methodology

With the aim of defining a methodology that allows experimentation with GMs and encourages critical analysis of their introduction into the industrial market, we have integrated the MDD methodology, and the steps presented by Karana *et al.* (2015), along with the DIY approach as an orientation that democratizes experimentation. The possibilities envisaged by this dialogue include a crossdisciplinary design approach that incorporates tangible experiments and the acquisition of new skills, as well as critical and verified analysis of points of alignment between material innovation and the industrial world.

Compared to the schema previously presented in Figure 2, the process has been expanded by integrating three phases related to DIY experimentation: a phase of Cognitive Experimentation as termed by the authors, a second phase focused on Innovative Experimentation, and a third and final phase termed Enabling.

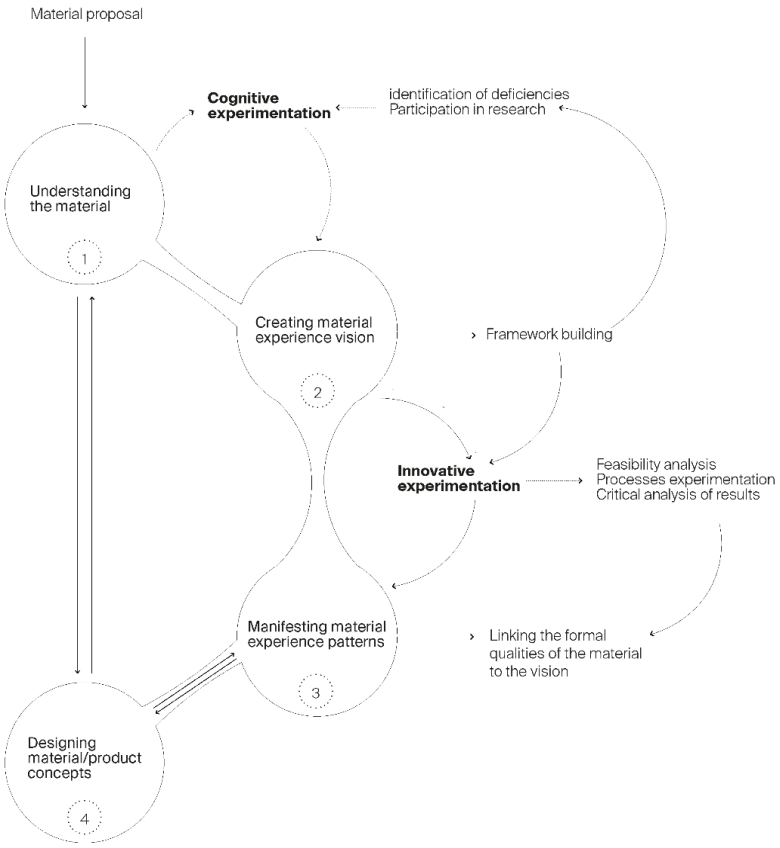

Figure 2. Methodology scheme presented by the authors

Cognitive Experimentation

The exploratory experimentation phase is positioned within the MDD framework between the material understanding and performance analysis, and the creation of a Material Experience Vision, which identifies potential applications consistent with the preliminary phase, i.e., verified material capabilities. Exploratory experimentation plays a role in deepening the understanding gained from the initial phase, guiding the designer to identify tangible material properties and verifiable observations. In the specific case of GM experimentation, the goal is to identify growth parameters that contribute to these performances, aiming to understand potential material modifications related to its vital components and ensuring their consistency.

The objective is thus to enter the envisioning phase with concrete and verified possibilities, facilitating the identification of new applications—a complex task given the innovation brought by regenerative materials, especially those whose performance varies with numerous parameters.

Furthermore, experimenting with the production processes of these materials involves developing a profound understanding and critical capacity to modify, redesign, and simplify these processes to alter their output.

The MDD phase dedicated to creating a Vision is thus facilitated not only by knowledge of the material but also by understanding the production process and its encompassed variables. Therefore, this step is bidirectionally correlated with exploratory experimentation because envisioning the potential of a material whose performance is easily modifiable implies the plausible need to alter the growth process and material output.

This possibility was observed during the application of the proposed methodology in this contribution to the design process involving BC, an LM produced from the fermentation of green tea and bacteria (Lee, 2011). In this case, exploratory experimentation involved evaluating optimal parameters to produce BC films within an acceptable fermentation time, with varying thicknesses to assess different mechanical performances. By testing the resistance of films with different thicknesses (Fig. 3), the ideal thickness for achieving films with good strength and acceptable production time was identified as 10 mm during extraction.

Figure 3. From the left: 4 mm thickness BC film, 7 mm thickness BC film, and 10 mm thickness BC film

The envisioning phase focused on enhancing the semi-structural properties by integrating the material into the upholstered furniture sector, subjecting it to tension. Given the aim to create a product demonstrating the ability to design not only with regenerative materials but also with conscious design principles using only natural materials and minimizing necessary resources, it was necessary to reorganize the exploratory experimentation phase. This phase was thus refocused on the possibility of reducing fermentation times, identifying parameters that allow minimizing resources required for optimized fermentation.

The exploratory experimentation phase was approached twice: first, to vertically understand the material, and second, to identify which parameters were modifiable to achieve results consistent with project goals. During both cycles, the methodology involved setting up experiments with materials suitable for production, daily monitoring of parameters, and at the end of the phase, systematizing and analyzing results to confirm or revise the envisioned outcomes.

Innovative Experimentation

The second phase of experimentation, termed 'innovative experimentation,' occurs following the creation of a material experience vision. This phase requires a project brief and objectives aligned with the verified capabilities of the material, as determined in both the initial MDD step and the exploratory experimentation phase. With the validation of achieving the objective using the analysed material, innovative experimentation aims to conduct a feasibility analysis of the created vision, experiment with production processes, and critically analyse the results.

While the exploratory experimentation phase verifies the material's capabilities, the innovative experimentation phase focuses on understanding the feasibility of the envisioned application. This involves analysing production processes and design requirements. This phase primarily concerns the designer's ability to leverage their design skills by developing the necessary tools and machinery and controlling different aspects of production (Bianchini, 2014). In the case of LMs, these skills must be applied to innovative production processes, evaluating their feasibility, optimization, and output.

Regarding the project involving BC applied to the upholstered furniture sector, it was necessary to determine which methodologies would enable coupling natural padding materials with BC—specifically in-situ coupling and ex-situ assembly—and identify the most suitable material for creating comfortable and high-performance padding comparable to expanded polyurethane. Following the selection of six natural-origin materials, both methodologies were tested for each material, and the results were compared. This analysis was conducted in terms of the product's aesthetic and mechanical quality, process optimization, and potential for industrialization. During this phase, experimentation involves producing samples that are tested using DIY methodology, which, while not empirically valid, allows for a qualitative and critical analysis of the hypothesized application possibilities.

Thus, we can assert that this phase involves an initial part of research and feasibility analysis, leading to the setup of experiments aimed at verifying both the hypothesized possibilities in the vision and critically analysing the obtained results. This helps identify the processes, materials, and key properties aligned with the specific design objectives. Given the close consequential relationship with the Envisioning phase and the third phase of the MDD, the step related to innovative experimentation has unidirectional exchanges with both mentioned project phases.

The phase dedicated to identifying the patterns through which material experiences manifest is enabled by the verifications on the feasibility of realizing the vision and the tangibility of the result in aesthetic and performance terms. This step leads to identifying one or more design possibilities dictated by the experience offered by the material in question, thus facilitating the subsequent phase of creating a product concept.

Enabling Experimentation

Within the MDD methodology, the concept generation phase involves manipulating components to obtain various material concepts, which subsequently lead to the final product concept, especially when starting from a material that is not fully developed (Karana *et al.*, 2015). With the proposed expansion in

this work, this possibility is extensively explored in the two previous experimental phases, arriving at the Concept Generation step with a clear schematic of the material's possibilities and limitations, as well as the explored domain. The creation of concepts within this new methodology, therefore, refers to finalizing the results obtained so far into an updated project idea relative to the previously constructed vision, ensuring coherence in both material and mechanical aspects throughout the experimental process.

In the case of designing with BC, the results previously obtained were systematized, analysing possibilities within the upholstered furniture scenario. The optimal type of furniture for demonstrating BC's application possibilities was identified, leading to its redesign following sustainable and circular strategies, such as Design for Disassembly and resource reduction.

Following the concept definition with considerations regarding its formal and functional aspects, an enabling experimentation phase was included. This phase focuses on designing technical and constructive details through reduced or full-scale prototyping. The goal of this phase is to test the constructive hypotheses derived from concept generation and definition, as well as the mechanical performances validated through non-empirical methodology in the innovative phase. It is structured into three stages: the first is dedicated to the project definition of the concept, including technical and material aspects; next is a phase for identifying suitable processes for prototyping and future production, concluding with a phase of testing regarding components, technical details, and targeted mechanical performances. These stages are essential for limiting the use of substantial resources required for full product prototyping to observe functional details.

Following the resolution of uncertainties regarding design and structural details, the experimentation phase leads to the creation of a prototype or the final product. This process involves resolving any issues, allowing for definitive testing.

While the prototyping and product development phase is part of the MDD framework, it is not considered critical within MDD because the methodology aims not only at identifying plausible innovative applications but also at participating in research related to new material development. However, given the different objectives of the research proposal in question, this phase becomes critically important. Specifically, in the case of designing with LMs, the purpose of the prototype is defined by Giaccardi (2019) as the desire to "support a process of reflection on the design activity and its outcome, what worked and what did not. In fulfilling this function, artifacts are used primarily in their evaluative capacity" (Giaccardi, 2019). Therefore, the prototyping phase is closely related to the previous enabling experimentation phase, including the possibility to reconsider and redesign the hypothesized production processes and conduct a second prototype for further evaluation. Prototyping can also lead the designer to reassess the proposed concept, resulting in redesigning processes, and so forth.

The iterative characteristic—continuously evolving through phases of proposals, testing, and modification occurring cyclically (Smith and Tjandra, 1998), influencing each other synergistically— of the design discussed here is of fundamental importance. This is due to the necessity of managing the application of an innovative material, its production process, and the design of the complete product. Furthermore, it is

essential to understand whether and how production processes are modified when transitioning from small-scale prototyping to full-scale implementation, associated with the general necessity in all projects to verify that the mechanical performance is suitable for the product type.

The creation of the second prototype thus concluded the design process, demonstrating the evidence obtained during each phase of the methodology, thereby summarizing them within a functional, verified product.

Results and Discussion

The methodology proposed here, applied to a design process—in this case, the creation of upholstered furniture with the integration of BC—allows for the verification of the effectiveness of the structured process. The objectives identified for each experimentation phase, as well as the correlations between these and the phases of the MDD framework, are compared with the results obtained for each phase of the design.

Examining the objectives set for the first experimentation phase, namely identifying gaps in research and literature regarding the knowledge and development of a GM, and active participation in the research, we can affirm that these are achieved through the bidirectionality established between creating a vision for application and the vertical knowledge phase of the material. This enables the identification and contextualization of different properties of the same material and subsequently altering the production process to achieve those specific, repeatable performances. In the case of designing with BC, identifying tensile strength, elasticity, and the sensory association with animal skin led to the possibility of using it as a semi-structural component in the upholstered furniture market. Following the phase dedicated to building a vision, which involved identifying application possibilities, it was also possible to set up ten experimentation cycles concerning the optimization of the fermentation cycle and minimizing resources useful for it, establishing a verified output as suitable and functional to the chosen sector and thus to the function associated with the material.

The second phase proposed as an integration of the methodology, innovative experimentation, instead sets objectives such as feasibility analysis and setting up and carrying out experiments related to the innovative production processes of the analysed material. To validate the feasibility of the vision and begin defining the first details such as production processes and materials, this phase requires the integration of the designer's skills with the literature related to GMs and already verified experiments. By doing so, it is possible to design and identify new production processes, new paired materials, and new structural possibilities. In the case of designing with BC, this phase allowed for identifying the suitable assembly method—such as ex situ assembly (Fig.4)—and the most performing material among the six selected for experimentation—such as natural latex foam. Following the validation of the feasibility of the vision concerning application possibilities and the identification of optimal methodologies for achieving a good quality product, it was possible to tackle the third phase of the MDD, which is related to the manifestation of the experiential patterns of materials. By analysing the reference type, i.e., the upholstery, and the obtained sample, a critical analysis was performed regarding the appeal of both.

Figure 4. On the left: Sample made of two layers of BC with cotton fibers padding, made with exsitu method; **On the right:** sample inserted in wood drum for the tensioning.

The results obtained and verified so far have laid the foundation for creating a structured concept, identifying an archetype within the target market—such as an upholstered stool—and designing it according to the previously established constraints. The design focused on adhering to Design for Disassembly principles, using wood for the entire structure and designing interlocking joints. Starting from the identification of the components forming the structure and their associated functions, the enabling experimentation phase led to the prototyping of the upholstery component at a 1:1 scale to verify how to scale and optimize the assembly process while achieving the same performance as the previously analysed scaled version. Additionally, resistance checks were performed on individual components, such as the end stops, where there were doubts related to mechanical performance. This entire phase resulted in the creation of a full-scale 1:1 prototype, on which necessary verifications were carried out regarding applied load stresses, joint resistance, assembly effectiveness, and the tensioning of the upholstery. These considerations necessarily led to formal and structural modifications, which were implemented through a re-evaluation of the concept's evolution, followed by another final prototyping phase.

Between the first and second prototyping, not only were the components modified to adhere to the previously identified design guidelines, but there were also changes in production processes—both concerning fermentation and CNC milling paths—to pursue the goal of optimizing time and resources necessary for production. For these reasons, the need to reevaluate the prototyping phase, which appeared marginal within the MDD framework, was confirmed. Additionally, it became clear that the three phases—concept design, enabling experimentation, and prototyping—needed to be correlated in a circular manner, highlighting the necessity for multiple verifications due to the introduction of an innovative material into established markets.

Conclusion

This contribution focuses on verifying the effectiveness of the proposed methodology through its application in designing products that integrate BC within an established market. This allowed us to examine how the research phases relate to the experimental ones, demonstrating new possibilities for designers in a landscape increasingly geared towards biocentric, regenerative, and sustainable design. The contribution aims to showcase the potential of a newly integrated methodology, which is why the section dedicated to methodology is more extensive compared to the subsequent considerations that serve

purely demonstrative purposes. The integration of theoretical research and tangible knowledge has provided a comprehensive overview of the material and its real-world applications.

Combining industrial design with innovative materials necessitates a re-evaluation of the concept of production time, which is currently linked to the cadence of industrial productivity. Integrating materials with inherent vital variables has revealed the limits imposed by these variables. Despite the potential for control and automation in the growth process, it remains subject to numerous non-parameterizable factors. This requires a reassessment of production time, aligning it with the regenerative timeline of materials to promote conscious resource use.

In pursuing the application of emerging materials within established markets, it will be crucial to consider their limitations and reevaluate production according to the regenerative principles applicable to all natural-origin materials, which, like GM materials, undergo a growth process.

Furthermore, attention must be given to the new possibilities for the designer's role within the evolving landscape of introducing new materials into the industrial scenario. The considerations outlined thus far address the initial question, asserting that the MDD approach, combined with the DIY methodology, can transform the designer's role and expand their possibilities and responsibilities. Through the intrinsic experimentation of the DIY approach, designers broaden their expertise in material biology, which, when integrated with methodical design skills and industrial production knowledge, opens up new design possibilities.

Initially, the adoption of a material-cantered design methodology within the broad field of LM experimentation, combined with a democratized approach that extends experimentation to the production process, results in the creation of artifacts that align with what Manzini (1990) described as 'the Third Way.' This approach allows the designer to adopt an intellectual attitude, participating actively in a broader research path beyond individual projects, not by providing precise, universally valid solutions, but by considering their product as a modest component of an open scenario, pursuing the constructive and critical role of design (Manzini, 1990).

Moreover, traditional industrial design involves understanding production processes to design coherent and feasible artifacts. In the proposed methodology, which focuses on the use of GM, the designer has the opportunity and necessity to design the entire production process suited to the product and the analyzed material, proactively contributing to the creation of a sustainable scenario.

Shifting the selection of materials from the final phase of design to the beginning of the process facilitates the development of plausible and coherent solutions for both the material and the market. This empowers the designer's role not only in designing objects but also in influencing social, economic, and environmental changes. The design process outlined and applied in the thesis aims to redefine collective social desires, habits, and values that have driven unsustainable practices so far (Williams and Collet, 2021), imagining alternatives to conventional production systems.

The multiple possibilities offered by adopting the proposed methodology in this contribution allow for future experimentation with materials different from GMs, validating other production possibilities and

new market sectors. This aligns with the interdisciplinary nature of the designer, dedicated to innovation not only in materials but also in form and function, and actively participating in responsible research and development.

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Exploring Design Strategies in Upholstered Furniture: An In-Depth Exploration through Case Studies

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Abstract

This paper examines circular design strategies by collecting and analyzing case studies that unveil the evolutionary pathways of upholstered furniture. The objective is to chart the implementation of circular strategies, focusing on design approaches within this sector. Upholstery furniture currently poses distinctive challenges at the environmental level due to the assembly of diverse and non-recyclable materials within the final product, the non-reversible assembly systems, and the lack of a specific disposal chain. The paper is structured as follows: firstly, a concise literature review categorizes potential drivers for sustainable design. Then, a case study analysis highlights the ongoing interventions in the design, production, service, life extension, and disposal phase's specific to upholstered furniture. This results in a curated collection of design approaches that may facilitate circularity within this sector, as they have the potential to instigate a paradigm shift, fostering the adoption of circular business models. The paper ends with recurrent trajectories and synergistic design approaches holding transformative potential within the upholstered furniture sector. The investigation contributes to the ongoing discourse on sustainable and circular design practices, shedding light on the challenges and strategic opportunities for designers, businesses, and policymakers aiming to re-design the evolving landscape of circular design in upholstered furniture.

Introduction

Within the Italian economy, the furniture industry represents a sector of considerable importance, both economically and in terms of design (Bruno & aL, 2022). At the European level, Italy stands out as the leading producer of furniture, with a production value of 17.5 billion euros (Forrest *et al.*, 2017). This primacy is also attributed to Italy's renowned design expertise, internationally recognized for its products' cultural content and territorial values (Turrini & Sbordone, 2020). The distinctive characteristics of Made in Italy, such as product diversity, formal and material identity, attention to quality, and strong local roots, attract collaborations and purchases from abroad (Turrini & Sbordone, 2020).

In this context, the upholstered furniture sector emerges as a significant production area, with numerous regional districts distinguished internationally for their competencies and capabilities. However, upholstered furniture plays a central role not only due to its production importance but also because of the disposal issues at the end of its lifecycle. The environmental management of furniture waste is a significant challenge, with an estimated impact of 10.78 million tons in the European Union in 2017, of

which about 2.5 tons consist of mattresses and upholstered furniture (Europur, 2021). According to Europur (2021), these wastes are generally disposed of as municipal solid or "bulky" waste, despite needing more specific differentiation.

There is an increasing urgency to develop innovative design solutions to reduce the environmental impact of upholstered furniture by adopting a holistic design approach, considering all constituent elements and the related construction and assembly processes. To avoid the proliferation of fast furniture products (Griffith, 2017), made with inexpensive materials and not designed to last (Maier, 2021), it is essential to guide companies toward Circular Economy (CE) practices (Cerulo *et al.*, 2022).

For various reasons, the focus on circularity and sustainability in the upholstered furniture sector is less established. Cerulo *et al.* (2022) identify five main factors: (i.) the environmental impact of disposing of textile and polyurethane materials, (ii.) the complexity of disposing of products made of mixed and (iii.) non-reversible assembled materials, (iv.) the logistical impact due to the weight of finished products, and (v.) a global supply chain. The choice of materials significantly influences each of these issues, and the sector's difficulty in adopting circular practices increases its environmental impact (Barbaritano *et al.*, 2019).

The upholstered furniture sector uses various materials, including wood, plastic, textiles, and metals, contributing to the high quality of Italian furniture. However, not all of these materials, how they are used, and the processes they undergo make finished products circular: while some materials are recyclable, production processes can be energy-intensive and generate high CO2 emissions (Bruno *et al.*, 2022). The environmental issues of materials highlight the urgency of integrating circular practices into the sector's design ethics.

Polyurethanes, fossil-based, non-renewable foams, are among the most critical materials. Assembled with other expanded plastics, they guarantee the desired softness. Still, they are difficult to separate at the end of life, contributing to CO_2 emissions and releasing toxic microparticles into the environment (Bruno *et al.*, 2022). Textiles used in upholstered furniture coverings also pose problems, often made with non-recyclable polyesters and sewn in a non-reversible manner, using rigid elements such as fasteners, making them difficult to wash, repair, and disassemble.

In this complex field, this study aims to trace the implementation of circularity strategies, focusing on design approaches within the upholstered furniture sector. This proposal aligns with Sustainable Development Goal 12, "Responsible Consumption and Production," particularly targets 12.5 and 12.6, which aim to significantly reduce waste generation through prevention, recycling, and reuse, and to encourage companies to adopt sustainable practices.

The article aims to examine the implementation of circularity strategies, focusing on design approaches in the upholstered furniture sector. This research is carried out through a detailed analysis of upholstered furniture case studies, of which the article explores their evolution in terms of circularity and sustainability. The following paragraphs present a review of the existing literature, ranking potential factors driving sustainable design and providing a basis for the subsequent analysis of the case studies. This is followed by the methodology adopted to analyze interventions in the design, production, service,

life extension, and disposal phases of upholstered furniture. The results outline a number of strategic design approaches aimed at promoting sustainability and facilitating the achievement of circularity goals in the sector. In the final sections, the paper summarises the critical conclusions from the collected data, highlighting recurring trajectories and design approaches with transformative potential for the upholstered furniture industry.

Literature Review

Human impact on the environment has escalated since industrialization, and the natural world is reaching or has already surpassed, a critical point where it can no longer sustain the biosphere as we know it (Sariatli, 2017). Signs of ecosystem deterioration are evident, and it is time for a change (McQuaid *et al.*, 2019). Our industrial economy has remained fundamentally linear, operating on a take-make-dispose model, and companies exploit resources to produce products, and consumers eventually discard them. This linear production model, dominant since the third industrial revolution (Jiang *et al.*, 2022), has brought prosperity but is unsustainable (Gale, 1989).

This linear economy must be replaced with a CE (Ellen MacArthur Foundation, 2013; 2015), which maximizes resource use, focuses on reuse, and aims to eliminate waste and emissions (Greyson, 2016). The European Commission (2020) associates the shift towards a CE with strategies like improving recycling and reducing waste, highlighting the role of innovative business models, sustainable design, and industrial cooperation in reducing greenhouse gas emissions and environmental impact (Bocken *et al.*, 2016). In particular, the Circular Economy Action Plan (EC, 2020) has made the CE a crucial strategy for long-term economic growth and global competitiveness. The concept, however, is not new; it originated in industrial ecology in the early 1990s with Robert Ayres' (1994) concept of industrial metabolism, which involves converting raw materials into finished products and waste within a stable system. McDonough and Braungart (2010) further emphasized closing "technical" and "biological" loops within a "cradle-to-cradle" framework.

The CE aims to retain the value of materials as long as possible by prolonging product lifespans or reintegrating them into the economy for reuse (Ayres, 1994; Stahel, 1994, 2010; Lifset & Graedel, 2002). Achieving a fully operational CE is challenging and remains an aspirational goal. A realistic interpretation of the CE acknowledges the inevitable dispersion of energy and materials. The Ellen MacArthur Foundation (2015) views it as a comprehensive framework based on fundamental principles, also known as the "3R principles" (reduce, reuse, and recycle). These principles have expanded to include "recover," "redesign," and "remanufacturing," forming the 6R framework (Jawahir and Bradley, 2016).

Is it possible to assert that the principles of the CE evolve from sustainability, focusing on systemic properties rather than specific elements (Ceschin and Gaziulusoy, 2016). In this context, Circular Design (CD) strategies advance sustainability by emphasizing resource reuse instead of mere usage, aiming for an industrial system that is restorative and regenerative (EMA, 2013). This transition, rooted in Design for Sustainability, supports the CE by introducing innovative approaches to resource management, ultimately seeking to close the loop in resource utilization.

The CD emphasizes a transition from resource consumption to greater resource utilization. We examine the natural progression towards CD aligned with the CE to understand this evolution. This shift originates

from Design for Sustainability (DfS) principles, fostering innovative approaches within the circular framework. DfS has been crucial in transitioning from a linear to a circular model (Moreno *et al.*, 2016). Ceschin and Gaziulusoy's (2016) work outlines various innovation levels within this approach, highlighting four distinct DfS innovation levels:

Product Innovation Level: Focuses on design approaches to improve or create new products, including Green Design, Ecodesign, Emotionally Durable Design, and more.
Product-Service System Innovation Level: Extends beyond individual products to integrated combinations of products and services, often involving new business models.
Spatio-Social Innovation Level: Pertains to human settlements and socio-spatial conditions, addressing scales from neighborhoods to cities, including Design for Social Innovation and Systemic Design.
Socio-Technical Innovation Level: Aims for radical changes in how societal needs are met, supporting transitions to new socio-technical systems.

Design plays a critical role in the evolution towards sustainability, transforming how artifacts are conceived and produced. The literature review shows how design facilitates circularity by redesigning artifacts, reassessing production processes, and exploring new materials. It also highlights the less-explored influence of design on behavior change among various stakeholders, especially users.

Adopting CD is urgent, transitioning from a linear to a CE. Designing within the CE requires shifting from a product-focused to a system-based approach (Bocken *et al.*, 2014; Moreno *et al.*, 2016; Ceschin and Gaziulusoy, 2016). Systemic approaches are categorized into "slowing loops" and "closing loops" strategies (Stahel, 2010; McDonough & Braungart, 2010; Bocken *et al.*, 2016). "Slowing" involves prolonged use and reuse of goods, while "closing loops" focuses on material reuse through recycling.

CD approaches can be classified into three macro areas: "Design for resource conservation," "Design for slowing resource loops," and "Whole System Designs" (Moreno *et al.*, 2016). In these macro areas, it is possible to identify the approaches related to the ecological transition. The authors, after reviewing the literature, propose the following selection of Design Approaches as the most pertinent for promoting the development of artifacts aligned with the principles of the CE: Design for Product Life Extension, Modular Design, Design for Reparability, Design for Disassembly, Design for Upcycling, Design for Material Efficiency, Design for Productive Resource Efficiency, Open/Collaborative Design, Emotional Design, and Product Service System Design. These approaches, together with the principles of the CE, form the basis of the analysis respectively presented in paragraphs 2.1, focused on the upholstered furniture sector.

To achieve an effective CE, strategies must be designed to promote circular production and consciously contemplate or modify user behaviors. For example, the sofa, a well-established product in the upholstered furniture sector, demonstrates sustainability shortcomings such as a short lifecycle and difficult disassembly. Understanding design approaches that promote behavioral change is crucial for improving the sustainability of such products.

Circular Design Approaches

After listing the CD Approaches that best align to facilitate the sustainable transition implementation, we will offer a short explanation for each.

Design for Product Life Extension focuses on creating durable, functional products to reduce frequent replacements. This approach involves selecting long-lasting materials, fostering emotional user-object relationships, and employing strategies like sharing or multi-functionality. By extending product lifespans, it minimizes resource depletion and waste (Stahel, 2013). According to this approach, the designer is tasked with identifying the maximum efficiency of the product-service and developing it to create value for one or more individuals in the long term, thereby optimizing resources.

Modular Design involves standardizing components and, when this is not possible, dividing them into sub-assemblies. These are recycled at the end of the entire product lifecycle into new products, or reused in different products. Modularity thus concerns not only the product and its components but also the production processes, to optimize resource efficiency even in the procurement and production stages. Therefore, designers and manufacturers must integrate social responsibility and ensure greater user satisfaction (Inoue *et al.*, 2020).

Design for Repairability aims to make products more accessible to repair by using common, affordable components, simplifying disassembly, ensuring spare part availability, and providing clear labeling and repair guides. It involves analyzing components' importance, failure frequency, and potential upgrades. This strategy also includes economic approaches and local infrastructure to support user adoption through DIY repairs or company-provided services (EC, 2019).

Design for Disassembly focuses on recovering products, parts, and materials to maximize value and minimize environmental impact. This involves non-permanent joints, clear disassembly sequences, and minimized parts and materials. Disassembly is analyzed through connector identification, tool changes, and component removal. It also considers disassembly times and user skills to extend product lifecycles and facilitate component replacement (De Fazio *et al.*, 2021).

Design for upcycling refers to the process of converting by-products, waste materials, or unwanted products into new materials or products of higher quality and environmental value due to the little energy input and less virgin material and avoiding transportation of new materials and products (Altamura & Baiani, 2019). Pioneers give various definitions of upcycling, all of which share the concept of adding value to a discarded product or material (Ahn & Lee, 2018).

Design for Material Efficiency measures how much material is needed to produce a product or service, aiming to reduce material use and associated impacts like emissions. Product design involves strategies like designing lighter products, reducing waste through innovative technologies, and reusing non-obsolete components. Effective material efficiency balances reducing material quantity with maintaining product durability and recyclability (Allwood *et al.*, 2013; Lifset & Ecklman, 2013).

Design for Productive Resource Efficiency aims to use Earth's resources sustainably, minimizing waste and environmental impact. This approach reduces errors, defects, and reworks during design, prototyping, and production, lowering costs and increasing productivity. Techniques like generative and optimization design evaluate product performance and efficiency. It also involves using renewable energy technologies to enhance resource efficiency (Nyamekye *et al.*, 2023).

Open/Collaborative Design leverages open licenses, digital manufacturing technologies, and open-source principles to create reusable designs for physical objects and systems. This approach promotes knowledge sharing and innovation as common goods, fostering a new design ethic. Applied in sectors like agriculture, wellness, and fashion, it aims for a positive social impact by accelerating the spread of innovations (Menichinelli & Cangiano, 2021).

Emotional Design explores the relationship between products and users, enhancing enjoyment and satisfaction, which can extend product lifespans (Desmet & Hekkert, 2009). Initially unconnected to sustainability, it links product attributes to lifecycle extension and responsible use. Understanding emotional drivers aims to extend products' physical and psychological lifespan, encouraging users to maintain them longer (Lobos & Babbitt, 2013).

Finally, a sustainable Product Service System Design (Vezzoli *et al.*, 2021) offers products and services to meet user needs through innovative stakeholder interactions. In this model, product ownership and lifecycle responsibilities remain with providers, who can pursue environmentally and socio-ethically beneficial solutions while gaining economic benefits. Key aspects include dematerialization, integrated offerings, easy product upgrades, and managing business model factors, promoting a shift towards circularity (McAloone & Andreasen, 2004).

Methodology

Potential drivers for sustainable design, previously categorized through the literature, now provide the foundation for the subsequent selection and analysis of the collected case studies, with particular attention to the types of upholstered furniture connected to the CE principle and practices and outlining the exploration field for the research project "Circular Sofa Platform" (CSP) embedded in the “National Recovery and Resilience Plan” PNRR - “Extended Partnership” PE11, Spoke 2, Made in Italy Circular and Sustainable (MICS). The CSP project aims to design and produce a new version of upholstered furniture focusing on sustainability and circularity. The aim is to develop innovative design solutions to reduce the environmental impact of upholstered furniture by selecting circular materials, creating modular systems for easy assembly and disassembly, and integrating intelligent solutions. The project aims to extend the durability of furniture and reduce its energy impact to a minimum through a holistic approach that includes all components and construction processes.

Referring to the previous paragraph on the study of the literature review (Knopf, 2006), and after outlining the exploration field, it emerges that examples of innovations related to this context are not gathered in a body of scientific literature that adequately traces their heterogeneity.

For this reason, the desk research methodology (Dixon-Woods *et al.*, 2005) was applied to structure this type of investigation. This methodology is based on the main online sources from manufacturers and trade fairs of national and international relevance. Exemplary products or product-services related to the reference theme were identified, as well as current best practices implemented by companies in the furniture sector, particularly in the field of sofas and armchairs.

This mapping is based on the previous application of initial filter marks that include adopting sustainable best practices and the most innovative aspects of the product-service system about the circular economy theme. This allowed identifying all ongoing design, production, assistance, life extension, and disposal interventions. Subsequently, this investigation was subjected to quanti-qualitative analysis through mapping case studies articulated in levels. At the first level, a collection of "light case studies" was facilitated by a form as a tool.

Case studies

It is helpful to emphasize from the outset that the focus of the mapping for the research on the first cluster of 'light case studies' is on individual products belonging to the upholstered furniture sector and not on the manufacturing companies. This is because companies need help comparing the best practices adopted due to variations in size and because some, due to corporate decisions, may concentrate only on certain production lines on circular logic.

For these reasons, it was decided to map individual products, expanding the research to the entire landscape of the Italian and global upholstered furniture sector, including various types of furniture, mainly sofas, but also armchairs, sofa beds, beds, and associated services.

Overall, the first mapping carried out, thanks to all the partners' proposals in the CSP project, led to the collection of 41 exemplary and representative case studies on the CE within the upholstery furniture sector. The initial proposals were consolidated, eliminating duplicates and cases of design solutions that had not yet reached prototypal maturity and/or production. Subsequently, the research was expanded to include databases of awards and recognitions related to the design world.

Thus, the collection includes case studies and best practices of companies, business associations, designers, and other organizations and institutions that have developed projects, product-services, and circularity strategies in the upholstered sector.

For each of the 40 selected cases, various types of information were collected through the design and adoption of a compilation tool to facilitate the collection and systematization of such information related to the exemplary cases to be mapped.

Figure 1 displays how the information appears once the layout format is properly framed. The sheet shows on the left the descriptive data of the product (product name, designer, manufacturing company, country and year of production, product type, and product maturity level - e.G, prototype/commercially available); a brief textual description including product photo; online reference; focus on materials used and special elements. On the right, the sheet lists the design approaches, CE principles, and CE business models (or pillars) addressed by the product and their connections. Some detailed pictures are displayed on the right, and a textual part of the discussion of design choices (type of production, product logistics, selling mode, after-sale, certifications) is presented.

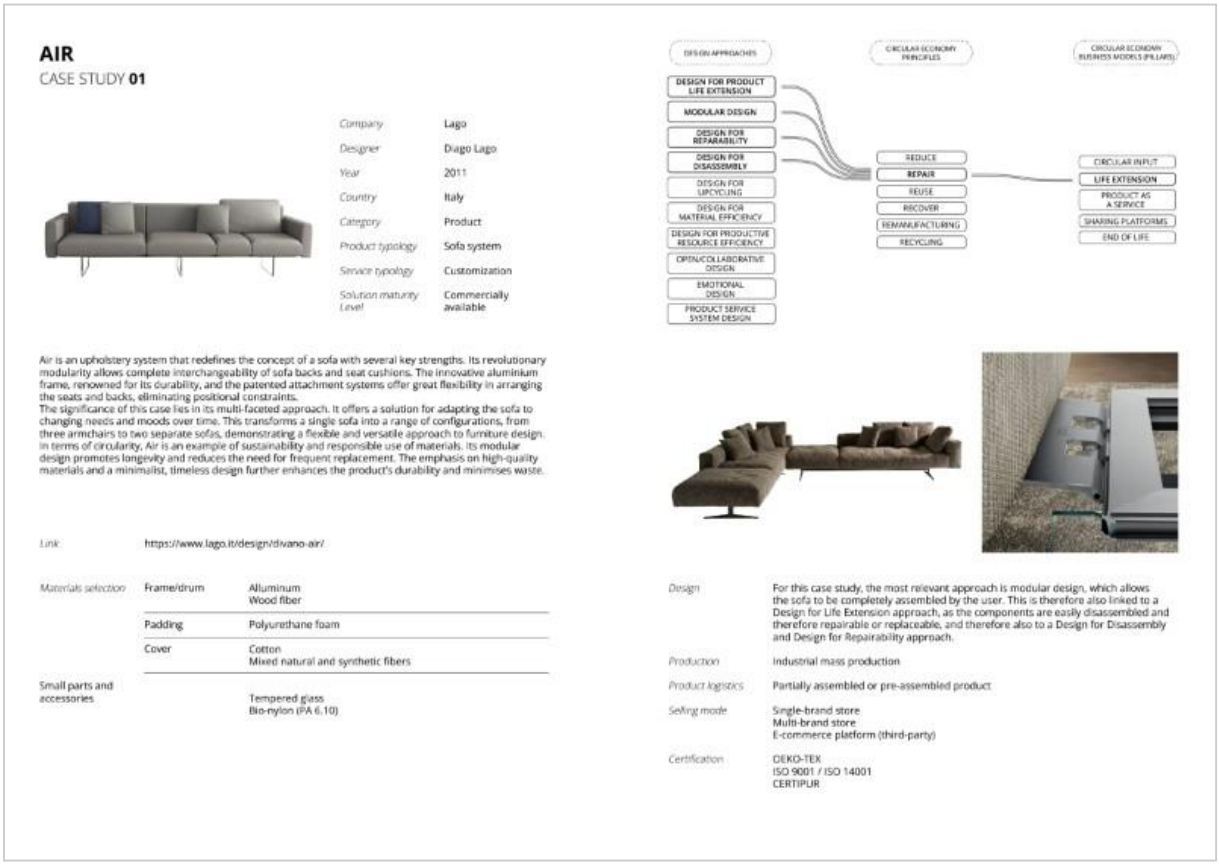

Figure 1. Layout case study example

The collected case study sheets were structured in Excel, with some sections formatted conditionally to cluster information for automated extraction. Figure 2 shows the setup of this data collection template.

This method aims to standardize information collection and bring out the first results in a structured and heterogeneous collection, thus comparing the initial results.

For this reason, once all the case study forms were completed and collected, it was possible, thanks to an overall schematization of the volume of said cases, to propose final considerations aimed at identifying trends in the transition towards circularity of some of the most exemplary products worldwide.

The cases were arranged alphabetically, and each form section was completed as required. In cases where certain information could not be obtained, the lack of data, which is challenging to retrieve through desk analysis, was highlighted as relevant to the mapping.

Cross-analyses were conducted between different product-services and the selected circularity strategies using filters. Upon completing this verification, selecting some of the most significant cases within the Italian territory made it possible to proceed with qualitative research, i.e., a more in-depth mapping of these so-called 'extended case studies'.

The interview protocol, created for the purpose, has several main sections, including product data sheet, summary description, key features, materials, design process, production process, logistics and distribution processes, use and maintenance, and post-usage and end-of-life. In addition, there is a free section to ask the interviewee to focus more on certain issues they consider particularly relevant.

Despite the choice based on geographic location, to facilitate connections between the research team and the relevant companies, conducting the interviews took a lot of work because only some were fully available to answer the questions. This situation led to a significant reduction in the responses collected, thus limiting the possibility of conducting a comprehensive and in-depth qualitative analysis. However, this contribution focuses on the results that emerged from the analysis of the light case studies.

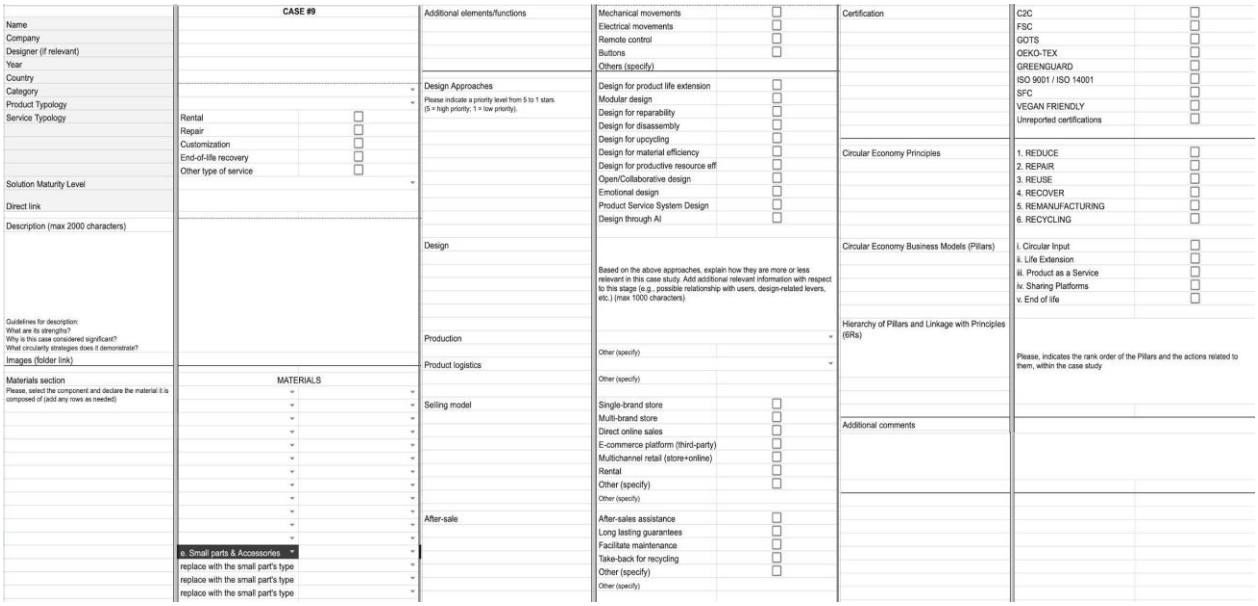

Figure 2. Case studies database (excel)

Results and Discussion

The 40 international case studies collection represents virtuous examples of CE practices in the upholstery furniture sector. This section details the tools used to analyze the cases and pertinent commentary highlighting gaps and recurring patterns within the evolutionary pathways of upholstered furniture toward circularity.

In the previous paragraph, the case study sheet was presented, describing in detail the data collected. In addition to the "project data section" and "material/structural composition aspects" of each product analyzed, the analysis unravels the ongoing interventions in design, production, service, life extension, and disposal phases specific to innovative upholstered furniture, suggesting the baseline for further future interventions. The most relevant aspect presented in this section is precisely the relationships and recurrences among the different product-service-system strategies implemented. These have been organized and re-read with respect to the principles of CE and CD described in section 2.

The 40 case studies collected (21 for the Italian national territory, while the remaining pertain to the global landscape) span approximately 15 years, with 32 covering the years between 2018 and 2023. The oldest case dates back to 2010. Regarding this aspect, it is interesting to note the increasing number of case studies conducted over the past four years. This is likely a response to the growing introduction of national and international policies — particularly European ones — aimed at promoting the ecological transition in the production sector. Additionally, increased awareness among citizens/users contributes to this trend, as they increasingly prefer to purchase products with a communicated and recognizable level of sustainability over mere economic convenience. The older cases, however, can be traced back to companies that have historically sought to introduce sustainability principles into their production chain. This effort is driven by concern for the environmental impact and the desire to rationalize the flow of materials and semi-finished products in their inventory, as the German company Bruhl exemplifies.

Additionally, among the case studies, only one pertains to a service: the comprehensive furniture repair service provided by Emmiera Group Limited. This UK-based company addresses a diverse range of issues, including structural repairs, enhancing comfort, and extending the lifespan of existing furniture through re-covering. They offer a holistic solution to furniture-related problems, combining expertise with product longevity. Their ability to fit new parts on-site during a return visit saves time and reduces the risk of further damage during transport, making this approach both cost-effective and environmentally sustainable. Table 1 presents the cases collected.

Table 1. Case studies list

	Product Name	Company Name	Year	Country	Link
1	Air	Lago	2011	Italy	link
2	Audrey	Nomad London	2018	United Kingdom	link
3	Blake	Ditre	2021	Italy	link
4	Bondi	Inside Weather	2021	USA	link
5	Brezza	S-Cab	2023	Italy	link
6	Casquet Classic	Biosofa	2012	Italy	link
7	Clouds	Iammi + ReMat	2023	Italy	link
8	Costume	Magis	2021	Italy	link
9	Couch in an Envelope	Ikea + Space 10	2023	Denmark	link
10	Croque La Pomme	Cassina	2019	Italy	link
11	Easy pieces forever	Bruhl	2010	Germany	link
12	Emmiera Group	Emmiera Group	2013	United Kingdom + Ireland	link
13	Ever	NaughtOne	2021	United Kingdom	link
14	Flock	Tacchini	2023	Italy	link
15	HB01	Habbio	2021	United Kingdom	link
16	Granbambola Le Bambole	B&B	2022	Italy	link
17	Lud'o Lounge	Cappellini	2020	Italy	link
18	Meda	InternoItaliano + Berto	2017	Italy	link
19	Mo Circular	Jeanne Blatter	2023	Switzerland	link
20	Newton	Doimo Salotti Noha Living	2018	Italy	link
21	Noha Sofa	Molteni & Co	2020	Germany	link
22	Paul	Parachute	2016	Italy	link
23	Pillow Sofa	Connubia	2022	USA	link
24	Reef	Velda	2022	Italy	link

	Product Name	Company Name	Year	Country	Link
25	Resleep	Metis	2018	Belgium	link
26	Saba	Lovesac	2023	Italy	link
27	Sactionalis	Ditre	2019	USA	link
28	Sanders Universe	Viccarbe	2021	Italy	link
29	Savina	Cassina	2022	Spain	link
30	Sengu Sofa	Arper	2020	Italy	link
31	Shaal	Oechsler AG	2022	Italy	link
32	Slope Chair	Designed for Life	2021	Germany	link
33	Sofa for Life	Lema	2019	Scotland	link
34	Soffio	Cassina	2023	Italy	link
35	Soriana	Prestoria	2021	Italy	link
36	Spectrum	Takt	2023	Italy	link
37	Spoke Sofa	A Lot of Space	2023	Denmark	link
38	The Sofa	Part & Whole	2020	The Netherlands	link
39	Total Sofa	Zanotta	2020	Canada	link
40	Za:za		2022	Italy	link

Key Findings Summary

A critical examination of the case studies was conducted using the analysis framework previously presented, which identifies three key interconnected CD factors: 1) the design approach used by the company, 2) the circular economy principle enacted, and 3) the CE business model enabled. For this reason, the data collected in these three sections were displayed through a graphical visualization when presenting all the information within each case study sheet. Figure 3 details each category, offering a comprehensive visualization of the framework used. For each factor, the frequency of each aspect investigated was quantified with respect to the totality of the case studies. The following paragraphs discuss the results of this quantification work for each of the three CD factors (design approaches, CE principles, and CE business model).

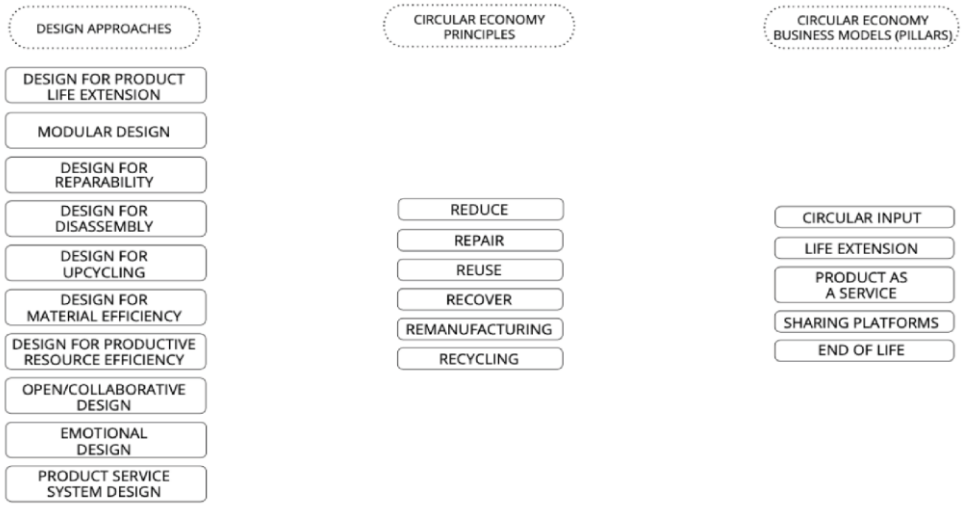

Figure 3. The three main categories, subjects of analysis

Design Approaches

Regarding the design approaches used by the companies, data reveal that strategies such as "Recovery" and "Remanufacturing" are scarcely used, as recovered and remanufactured items are rarely reported. Additionally, there are significant gaps in factors such as "Open/Collaborative Design," which was not adopted in any of the cases (figure 4).

In contrast, some approaches are more recurrent, such as "Design for Product Life Extension" with 33 out of 40 cases, "Design for Disassembly" with 30 cases, "Design for Reparability" with 26 cases, and "Modular Design" with 20 cases. These approaches form the canonical basis in the Design for Circularity perspective. The least adopted approaches are "Design for Material Efficiency" with 10 cases, "Emotional Design" with 3 cases, and "Product Service System Design" with only one case, namely "The Sofa" by "A Lot of Space." This case is distinguished by an efficient structure simplification that facilitates repair or replacement. Furthermore, the company intends to repurchase the component or the upholstery to be replaced, subsequently assuming responsibility for its recycling.

Interestingly, while some design approaches aim only to satisfy one of the CE principles, others support multiple principles, thus being more efficient in terms of circularity. For example, "Modular Design" can promote recycling, recovery, and repair, depending on how the approach is implemented and the goals. Similarly, "Design for Disassembly" favors both recycling and repair. Thus, the inferences between design approaches and CE principles are more intersecting and less linear.

At the same time, there is a direct correspondence between CE principles and CE business models (pillars). Therefore, it is insightful to understand where specific approaches intervene in the various CE principles, which favors the realization of the CE business models (figure 4).

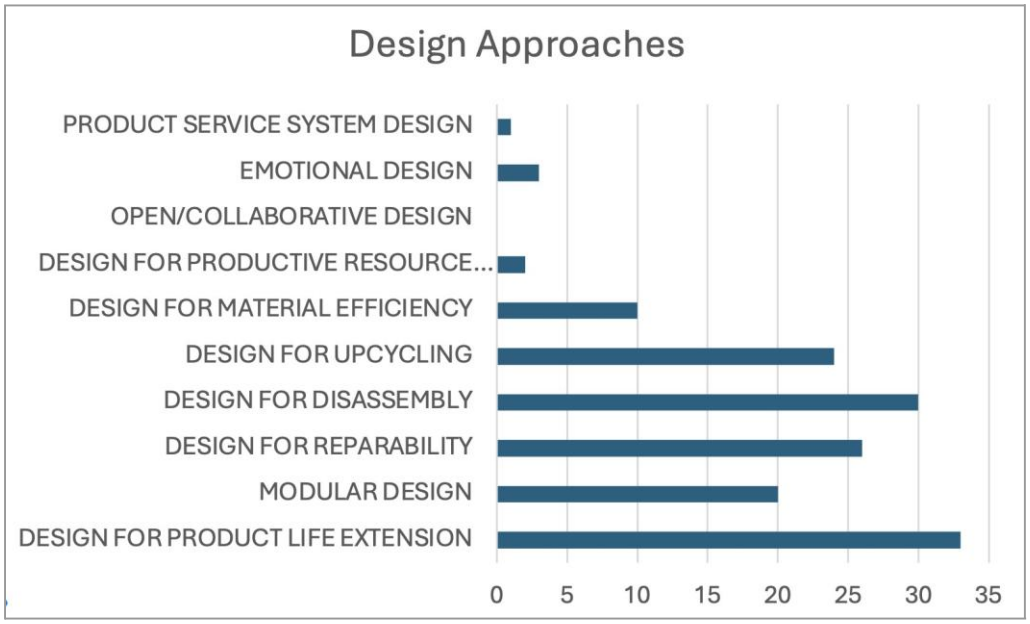

Figure 4. Design Approaches Adoption

Circular Economy Principles

At the level of CE principles, the most prevalent are 'Recycle', 'Reduce', and 'Repair' (figure 5). This trend is consistent with findings within the Italian territory, where "Recycling" is the preferred practice among the 6Rs of CE. Other principles, such as 'Repair', 'Reuse', and 'Remanufacture', are also gaining traction, particularly within small businesses (Ghisellini & Ulgiati, 2019).

Specifically, the adoption of CE approaches reveals that reduction is the most common, with 26 cases, followed by recycling, 25 cases, and repair, 23 cases. The least adopted approaches are recovery, with 10 cases, followed by reuse, with 6 cases, and remanufacturing, which was adopted in only one case study, "Blake" by Ditre.

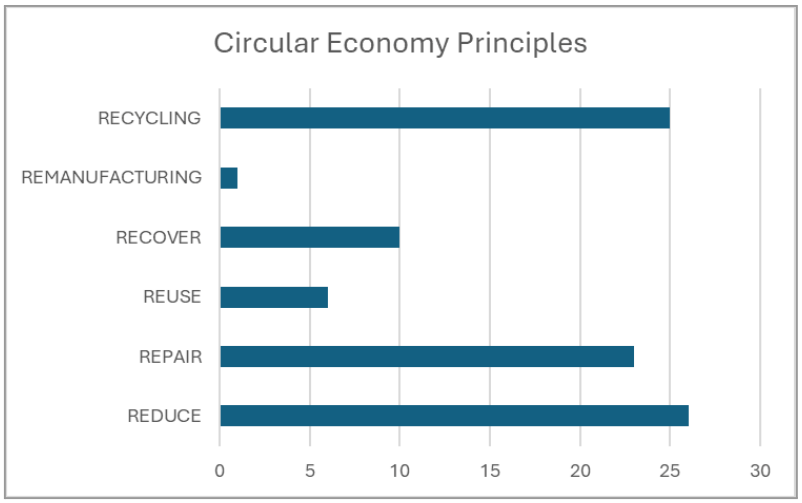

Figure 5. Circular Economy Principles Adoption

Circular Economy Pillars (or Business Models)

Finally, regarding CE business models (pillars), the most recurrent are "Circular Input," "Life Extension," and "End-of-Life," with "Circular Input" implemented in 30 cases and "Life Extension" and "End-of-Life" each in 28 cases (figure 6).

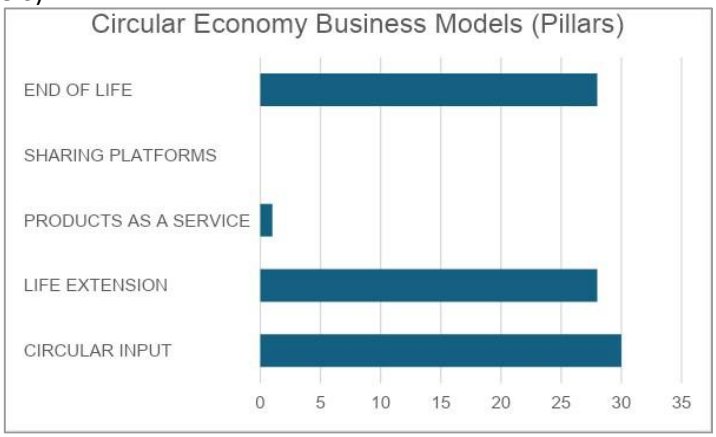

Figure 6. Circular Economy Business models adoption.

A notable gap within this category is the scarcity of "Sharing Platforms," which are not adopted in all cases despite their potential to enable CE principles on multiple levels. Additionally, the "Product as a Service" approach is also minimally adopted, with only one case, "Spoke Sofa" by Takt.

Although current discussions around CE emphasize product-service systems (PSSs) as an added value for enabling CE business models, this approach is not highly valued. It does not emerge as a determining element within the furniture industry.

Overview

The three key CD factors were correlated for each case study to highlight their relationships. The Design Approaches to which the case responds were indicated by an arrow. In turn, the Design Approaches were linked to the reference CE Principles that the project aimed to achieve and then to the CE Business Models. The interconnection between design approaches and CE principles is defined qualitatively by analyzing design choices applied to each product. The interconnection between the CE Principles and the CE Business Models is defined from what is stated by the designers/companies, as well as by interpreting the available information. Figure 7 represents some possibilities retrieved from case studies of how the three elements interconnect with each other.

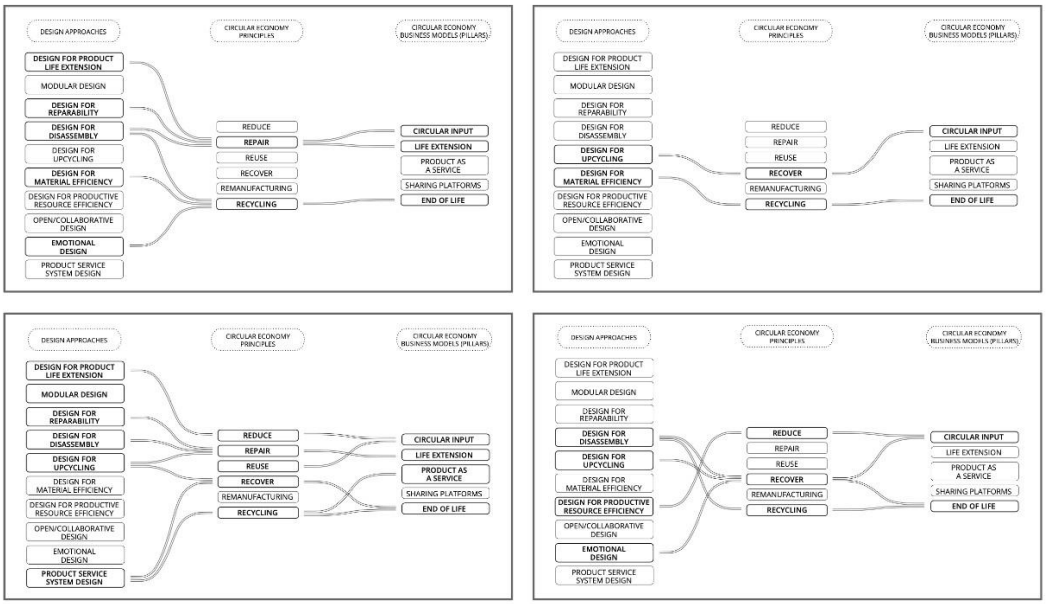

Figure 7. Three key circular design factors related to cases 7, 11, 18, and 38 respectively

The correlations among each case's three key CD factors were then analyzed crosswise. Comparing the cases collectively, relevant reflections arise (figure 8). The graphical representation returns the frequency of connections between the three categories and shows how they connect by highlighting the most recursive and densely populated interconnecting relationships. Among other exciting reflections, while some design approaches aim only to satisfy one of the CE Principles, others favour more of these principles, thus being more efficient in terms of circularity.

For example, *Modular Design* can promote *Recycle*, *Recover*, and *Repair*, and different factors can emerge from the same approach, depending on how a given approach is channelled and the goals. As such, Design for disassembly also favors both recycling and repair.

Thus, the inferences between Design Approaches and CE Principles are more intersecting and less linear. At the same time, there is a direct correspondence between CE Principles and CE Business Models (Pillars).

In looking at the reported results in the graphical form of this mapping, it is attractive to understand where specific approaches intervene in the various CE Principles and, consequently, which of these favor the realization of the CE Business Models (Pillars). After that, at the level of CE, the most repeated and present are those of recycle, reduce, and repair, while among the CE Business Models (Pillars), the most repeated are Circular input, Life extension, and End-of-life.

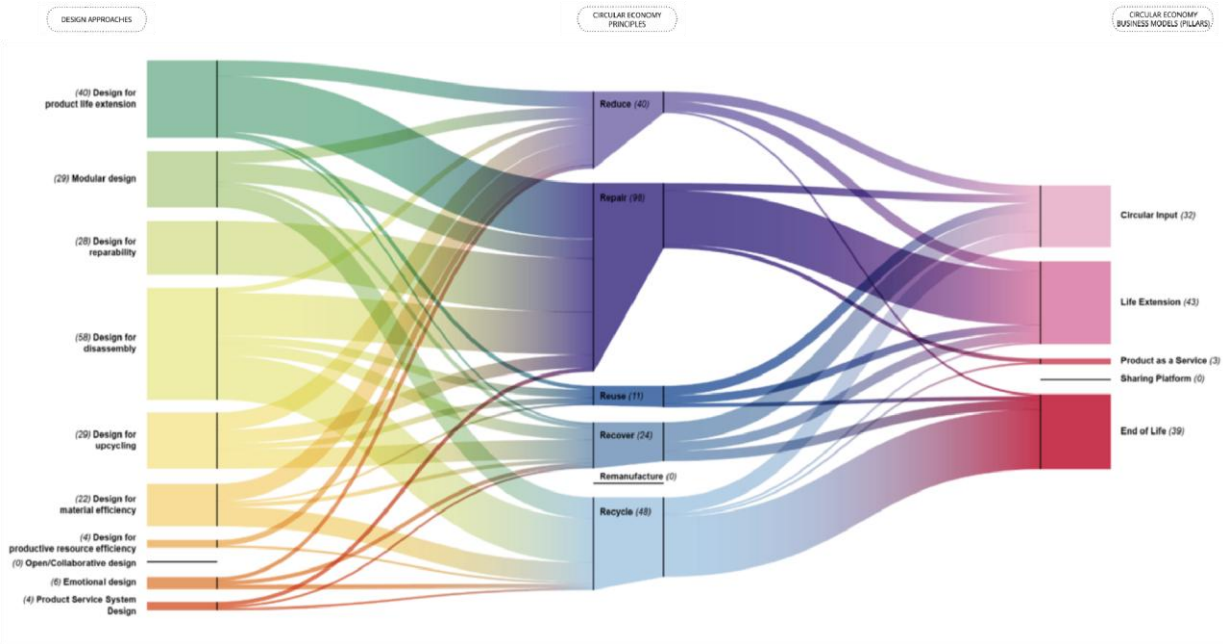

Figure 8. Overview (sankey diagram)

Conclusion

The article proposes a reflection on the current state of circular upholstered furniture production through an in-depth analysis of national and international case studies and the circular approaches applied and/or adopted in that sector.

A multilevel and complex landscape emerges from the research, where circular approaches, methodologies, and principles, when applied, act on the different stages of the production chain, from conception to production, sale, and disposal, each influencing the sofa's components, their shape, materials, assembly, and use.

The critical reading of CD Approaches, CE Principles, and CE Pillars, first defined in the literature and then found and analyzed in the 40 case studies presented, has made it possible to define a grid of interventions narrating circularity in the upholstered furniture sector today and help delineate the preferred and future areas on which to act tomorrow.

This analysis represents the pool of useful interventions to identify strategic opportunities for designers, companies, and policymakers to reshape the evolving landscape of CD in upholstered furniture. At the same time, the obtained results could be useful also in a different sector, because the CD Approaches, CE Principles, and CE Pillars are not strictly related to the upholstered sector.

This analysis paves the way for the next steps in the Circular Sofa Platform project, from which the research originated, whose aim is to develop innovative solutions at the product-service and process system level that aim to extend the lifespan of upholstered furniture, reducing the energy footprint of the final product and, at the same time, enhancing and implementing the heritage of industrial and craftsmanship knowledge present in the various Italian production districts.

In fact, based on this observation, the project is focused on creating PoCs of upholstered furniture capable of implementing circularity strategies through the informed application of CD strategies.

Acknowledgement

This analysis is part of the research for the implementation of the Circular Sofa Platform (CSP) project, funded by the European Union (Next Generation EU grant) through the Ministry of University and Research as part of the National Recovery and Resilience Plan (PNRR). CSP is an ongoing research endeavor that expands and delves deeper into the themes outlined in the paper. CSP is within Spoke2 of the extended partnership 'Made in Italy Circolare e Sostenibile' (MICS).

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5c. Circular Economy

Abstracts

Submission ID: 7

Transitioning Towards a Circular Household: Exploring Drivers and Barriers

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Abstract

The adoption of household circular economy practices is fundamental in the transition towards sustainability, but still underexplored, with individuals not fully realising the pivotal role they could play in society's progress. Despite the arguments inherent to these practices, such as financial benefits, lower environmental pressures, and well-being – in an intergenerational context –, circular practices and initiatives remain concentrated on environmental silos, focusing on isolated topics, such as waste recycling, energy efficiency and water savings, rather than exploring the factors for change through integrated circular thinking. Multiple studies have documented the drivers and barriers linked with the implementation of circular strategies and practices in private or public organizations, eco-industrial parks, and cities. Nevertheless, there is still a lack of knowledge regarding the motivational factors and inhibitors associated with household circular economy activities. Thus, the present work aims at comprehending what drives and inhibits individuals from fostering circular economic progress at the household level. This study is supported by a triangulation approach, combining an integrative literature review with the results derived from semi-structured interviews with householders. The integrative literature review enabled the categorization of the data obtained through the interviews, while outlining the theory present in the scientific body of literature. The findings of the semi-structured interviews indicate that the drivers and barriers could vary between consumer stages. The householders can be negatively influenced by the lack of awareness of the existing benefits, an inadequate structural context (i.e., unaligned legislative framework or physical infrastructures), and a market offer with insufficient quality (i.e., low accessibility, availability or quality of circular products and services). On the other hand, the adoption process of circular economy-related practices significantly depends on the attitude of each individual and can be driven by the possibility to reduce the cost of living, the lifestyle of each householder, such as localism, and minimalism, and the ability of the product to include digestible information, regarding its sustainability performance. Additionally, key recommendations, supported on the householders' insights, for the development of public policies and market strategies were proposed, including public subsidies with reduced bureaucracy tailored to minimize the financial pressure of circular practices with a high initial investment, and transparency and disclosure of the sustainability performance of the retailed products (e.g., a sustainability score). This research contributes to the ongoing debate regarding the role of householders in circular economic progress.

Submission ID: 8

Towards a Circular Lifestyle: An Integrative Review on Household Circular Economy Assessment and Disclosure

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Abstract

As a key driver for the Sustainable Development Goals, the circular economy model has been increasingly gaining attention from academics, companies, policymakers, and individuals. On the one hand, this concept helps define a roadmap towards sustainable development, and, on the other hand, it presents tangible solutions that can be implemented at different levels, including consumers, companies, eco-industrial parks, and cities. Householders, in the form of consumers or citizens, hold a pivotal role in society's progress towards a sustainability, representing a core component in the adoption of circular economy strategies. The assessment and communication of these actions has been highlighted as a tool, to foster the efficacy and dissemination of these practices. Several research studies have been conducted to provide insights on the state-of-art of circular economy assessment and reporting in products, organizations, eco-industrial parks, and cities. However, the scientific body of literature on circular economy assessment and disclosure at the household level is still at an embryonic stage, showing various gaps of knowledge and possible research avenues. Thus, the present work aims at exploring the current state of knowledge on the circular economy assessment and disclosure models at the household level. This research study is supported by a systematic literature review of the existing body of scientific and grey literature. It leverages topics associated with approaches, concepts, methods, and frameworks, as well as case study applications. The study covers three subtopics: (i) household circular economy assessment; (ii) circular economy disclosures; and (iii) political landscape enabling circular economy progress at the household level. The systematic literature review will provide an overview of the present trends in research related to these areas, recognize the key limitations, assessment, and communication methods, and identify research gaps. Building on this foundation, it will provide a theoretical framework for the subsequent studies, underlining possible areas of contribution. This research contributes to the debate on the role of the household in the transition towards a circular economy, and its inherent assessment and communication.

Submission ID: 25

Assessing the Adoption of Circular Economy Strategies and Practices in the Third Sector: Survey Investigation of Portuguese Catholic Organisations

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Abstract

Circular economy (CE) is a concept that could allow organisations to become more sustainable. In addition to businesses and public entities, one significant sector of our society is the third sector which provides services in various areas with great impact globally. The organisations in this sector can facilitate the adoption of CE practices through advocacy, education, and internal practices. Therefore, their transition from a linear to a circular model is desirable. However, there is a scarcity of empirical studies researching on CE at the organisational level of third sector organisations. Through a literature search, several factors were found to influence the implementation of CE activities in third sector organisations such as technology, technical support, training, capital requirements or transaction costs. CE in organisations therefore includes a diverse group of practices that demand detailed examination to understand the implementation process. Hence, this study aims to outline the present state of incorporating circular practices and strategies using Portuguese catholic organisations as our case study. Catholicism in Portugal plays a significant role culturally and traditionally. According to the 2021 Census, about 80% of the Portuguese population identifies as Catholic and the influence of the Catholic Church and its organisations is undeniable as they account for 30% of the national social third sector. The study will also cover the barriers and motivations inherent to CE implementation. For this purpose, an online questionnaire survey will be distributed to Portuguese organisations affiliated with the Catholic Church (around 1,500 organisations). This article will address the preliminary findings. This research can potentially assist practitioners and researchers in the transition towards circular practices in the third sector, particularly within religious organizations. It can play a pivotal role in the identification of circular opportunities within these organisations and contribute to the development of a future approach for the gradual implementation of circularity, with a particular focus on its application within Catholic organisations.

Submission ID: 52

The Circular and Transdisciplinary Approach for Sustainable Cacao Postharvest Production in Arauca, Colombia

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Abstract

Agri-food systems are a key sector for a sustainable society. In fact, sustainable agri-food systems contribute to income generation for rural populations and small farmers. Conventional agri-food systems lack technological innovation, particularly in the first mile of the value chain, and regularly small farmers operate without standardized processes, resource efficiency in production systems, or considering the knowledge transfer between the system stakeholders. The use of analytical models in the design of the value chain, innovative circular business models and the co-creation between different actors in the agri-food systems could enable the transformation from conventional towards sustainable systems. This research focuses on the design of circular business models for agri-food systems incorporating operations research tools into farmer´s decision-making processes. This allows them to enhance their agri-food systems and facilitate their transformation into more sustainable systems. We aim to develop a collective and sustainable postharvest model production for the cocoa agri-food system in Arauca, Colombia, including Circular Economy-CE practices in the transformation, improving technological innovation, creating cooperative structures, and improving profits for cocoa farmers.

In cocoa transformation, as with many other agricultural sectors, numerous residues or byproducts often go unused (the main byproducts of the cocoa transformation are cocoa pod husk, mucilage, and bean shell). Creating a business model for agricultural products that integrates CE practices will secure a significant enhancement in farmers´ productivity, environmental sustainability, and particularly, their profits, contrary to the limitations of the traditional business model approach in agri-food chains. Also, by taking a transdisciplinary approach, the researcher engages with system practitioners in the capacity building and co-creation of circular business models using data validation tools, participative modeling, capabilities transfer, and validation of the analytical models. This is highly relevant since these practices facilitate a shared understanding of the agri-food system and will provide training to the primary users, who will afterward employ them to assess the feasibility of the model.

The learnings on the design of agricultural business model integrating CE practices and the contribution of collaborative working and analytical tools for decision-making processes in transforming the cocoa agri-food system in Arauca from conventional to sustainable can be used in other regions or even other agri-food systems.

This research focuses mainly on Sustainable Development Goal 12 (Ensure sustainable consumption and production patterns), mostly in target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources. Furthermore, developing sustainable management in agri-food chains can improve sustainable livelihoods for farmers, particularly in rural areas from developing countries.

Submission ID: 66

An Empirical Study on the Industrial Hemp Potential in Nepal: Production and Valorization Perspectives

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Abstract

Hemp, a versatile and sustainable crop, has multiple economic and environmental benefits. Although hemp biomass is used to produce fiber and the seed is available in the market, its cultivation is illegal in Nepal. The government of Nepal has shown interest in legalizing cultivation, yet no study has been reported that has assessed the industrial hemp potential and investigated its benefits. And still, there is confusion regarding psychoactive and non-psychoactive hemp varieties. The study has filled the gap by identifying areas with potential hemp cultivation and estimating its annual production potential with the valorization possibilities. Considering the thematic maps of various parameters, such as land use practices, soil properties, and climate, and using ArcGIS, suitable land for hemp cultivation ($\geq$ 1 ha) has been identified. The identified areas were further categorized into low, medium, and high potentials, and considering medium and high potential lands, the hemp biomass and seed production potential were estimated. The study identified a total of 1,849,481 ha of land suitable for industrial hemp cultivation, and excluding low potential area, about 5.6 million metric tonnes (Mt) of biomass and 3.4 Mt of seed is estimated to be produced annually. Construction materials, textiles, and bioenergy (such as pellets and biodiesel) can be produced from hemp biomass and seed. The study's findings could be used to advocate for the government to legalize hemp cultivation in Nepal and attract entrepreneurs to establish hemp-based industries.

Submission ID: 69

Metabolism Practice for National Strategies of Circular Economy

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Abstract

Metabolism study is one of the essential methodological approaches of the industrial ecology field. Since decades, this academic field studies the types and volumes of physical resource flows at diverse system levels including national economies. Outcomes of metabolism study generate knowledge on composition, sources, volume, destination, and efficiency of resource use.

Physical resources are also at the heart of circular economy models, as a language that aims to transform the link between economic growth, natural resource depletion and environmental impacts. Public policy making for circular economy transition requires multi-disciplinary governance structure for negotiations of targets. As such, the public policy-making process implies decision-making about scenario analysis, and priority setting for scaling innovative circular production and consumption systems.

Traditional governance structures for environmental policy-making focus resource flows from a disciplinary perspective in diverse institutional settings. For example, water as a resource is regulated by specialized water institutions, biomass by agricultural related policy, energy and waste by specialized ministries. These public institutions operate independent information systems, and have singular priority settings. Moreover, the diverse public institutions often lack capacity for holistic interpretation of physical resource use on the scale of the national economy. The foregoing, makes the priority setting for decision-making in public policy process on circular economy, challenging. Metabolism study of national economies offers a governance structure for integration of the diverse disciplinary institutional perspectives on physical resource flows, by classifying input, output of all flows and stocks of a national economy including the integration of fragmented databases.

This research, studies the case of the National Strategy of Circular Economy of Uruguay, to understand how the practice of metabolism practice contributes to priority setting in the public policy making process. The action research methodology followed a transdisciplinary approach including capacity building of representatives of diverse public institutions, integration of diverse databases on a variety of resource flows, and iterative interactions among academic researchers and representatives of ministries and public institutions, for advancing metabolism study and decision-making on policy priorities. The outcomes of the transdisciplinary process include the formal adoption by the government of Uruguay of the National Strategy of Circular Economy. The contributions of this research highlight the importance of resource flow analysis as a baseline for national strategies circular economy and propose best practices for metabolism study as part of a transdisciplinary public policy-making process.

Submission ID: 88

Social Innovations for a Circular Built Environment: Case Studies on Solutions Proposed by Users and Practitioners

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Abstract

The built environment (BE) as a central part and environment of our everyday life is facing pressing issues such as high CO_2 emissions driving climate change, and resource scarcity, with construction activities being a major contributor to both. It is responsible for a significant share of CO_2 emissions (WEF, 2016), the consumption of a large portion of available resources (De Wit *et al.*, 2018; Schiller, 2020), and the generation of construction and demolition waste that again make up the bigger share of global waste. So, shifting "traditional", linear production and consumption practices and patterns towards innovative, circular ones by *slowing, closing, or narrowing resource flows* (Bocken *et al.*, 2016) is a substantial part of the solution to these problems.

As a contribution to the debate on transitions in practice and everyday life, this research focuses on the role of social innovations in facilitating this transition. It adopts a case study design and presents projects that promote change in the BE by introducing *new ways of doing, thinking, organizing, or framing* (Pel *et al.*, 2020). To that end, it dives into three different types of social innovations:

- Adaptive reuse of existing buildings through cooperative buying: an innovative ownership model (new ways of decision making) slowing resource flows.
- The (commercial) reuse of building materials and building parts represents new practices within the construction value chain, providing knowledge about reusable building materials, representing new ways of knowing, and both slowing and closing resource flows
- Using new technologies like 3D printing of buildings and building parts represents new practices and narrows resource flows

Semi-structured expert interviews were conducted to gain initiators' and practitioners' insights, and evaluated using a qualitative approach. The main findings differ between contexts: the initiating group: the cooperative buying groups included as well as one building parts reuse provider have an activist character. Their biggest barriers are access to financing of their projects as well as lack of support from governance structures, while they cite support from their network their biggest enabler. Business actors such as initiators of 3D printing in construction or building material platforms have more stable financing options, but lack the public awareness and trust in their ventures. However, they benefit from their technologies' innovativeness and the interest among their peers and target groups.

The study highlights the potential of social innovation in solving problems related to the built environment. By thoroughly looking into exemplary social innovations, this study underscores their significance in shaping a sustainable future through challenging traditional construction practices and offering new approaches to address the issues facing the built environment. Finally, it aims to outline possibilities for society and governance to enable and support such social innovations.

Submission ID: 93

Measuring Circular Economy for Organisations from Resource Decoupling Perspective

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Abstract

Sustainable raw materials production and consumption is a key element of industrial and circular economy (CE), social welfare and justice. With digitalization, decarbonization and growing standards of living worldwide, the demand for mineral raw materials has been increasing. The recent global energy crises and Russia's war on Ukraine have exposed vulnerabilities to the security of the supply of raw materials, which is one that must be considered and addressed, issues in global policy and monitored within SDG 12. Target 12.2 is measured by two indicators; raw material consumption and domestic material consumption. They are close correlated with resource decupling, which can be important indicator for raw materials policy and security for many countries and regions. Decoupling has been put forward as a policy goal by the International Resource Panel that distinguishes two types of decoupling (UNEP 2011): resource decoupling (economic growth and the level of primary resource use); and impact decoupling (economic activity and its environmental impacts), as measured by impact and state indicators. Nowadays decoupling might be widely recognized as the overarching goal of the CE, but has not been operationalised and rarely features as an integrated part of the transition process. For example, OECD in report (2020) collected 474 CE-related indicators, between 2018 and 2020 from 29 CE studies. Indicators on resources and materials represent only 9% of the framework, measuring material flows (exports and imports), the self-sufficiency of materials and the recovery of materials whereas decoupling has not been identified in the whole report. Moreover, as indicated by Lindgreen *et al.* the field of CE assessment has a low level of maturity, and the level of implementation of CE assessment approaches by organizations appears to be limited.

The aim of this paper is to identify and validate CE indicators applicable to companies across various sectors, with a focus on the concept of resource decoupling. Additionally, the paper examines limitations associated with the implementation, knowledge, and acceptance of these indicators among projects in Poland and UEA. This analysis is based on a comprehensive literature review, survey, and questionnaires. Our previous research (oto-GOZ) conducted in Poland showed that there is high potential for increasing decoupling through the application of CE business models. It was revealed that most companies, especially SMEs, are not prepared for indicators based on life cycle assessment methodology and monitoring of raw materials resource consumption, including critical resources. Based on these results, it was proposed to utilize tools such as the Complex Circular-Economy Quality Indicator (Kowalski *et al.*, 2023) and IT models to support decoupling and implement CE models. Moreover, these indicators have been implemented as incentives in policies and applied in Polish research and investment programs to support investments and new technological solutions." A case study based on the use of geothermal energy in the Carpathian mountain area has been also presented.

Submission ID: 107

Environmental Sustainability in Cement Industry: An Integrated Approach for Green and Economical Cement Production

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Abstract

Cement industry is one of the leading contributors of greenhouse gases after power plant industries. Approximately 4.1 billion metric tons of cement are currently produced globally every year, accounting for about 8 to 10 percent of global anthropogenic CO_2 emissions, and is expected to continually increase in the future adding more CO_2 into the atmosphere. The cement and concrete industry searches for ways to meet increasing demand while reducing the carbon footprint of the concrete produced. Techniques such as carbon capture and storage (CCS), material substitution, alternative fuels, and energy-efficient technologies have been identified as some of the approaches to producing more sustainable cement. Regardless of extensive research on novel techniques for reducing the environmental impacts of cement production, commercial implementation has yet been a concern and will occur only if there is a real synergy between sustainability and profitability. Most of the current studies, however, prioritize environmental aspects and lack exploring the socio-economic aspects. The commercial rollout of technology is impossible without public acceptance and until the plant owners and stakeholders see the economic values.

This paper proposes an integrated approach for environmental sustainability in cement industries where the traditional approach of cement production is combined with modern and emerging technologies. The CO_2 captured from the cement plant will be utilized within the plant for producing nano calcium carbonate ($CaCO_3$) for use in cement manufacturing process. This technology incorporates all the existing approaches and helps cement industries produce sustainable, durable, and economical cement while reducing CO_2 emissions into the atmosphere: thus, leading towards green infrastructure and global environmental sustainability. Additionally, the adoption of this technology ensures proper dispersion of nanomaterials thereby improving the performance of concrete. Further, this technology is economically attractive to cement industries as they will have a new product (nano $CaCO_3$) with a much higher cost than cement with the potential of additional economic revenues.

The proposed abstract relates to SDG 9.4, SDG 12.4, and SDG 12.5. It is relevant to the conference topic as cement is the second most used resource in the world and has a larger footprint in every region of the world. Appropriate technology for sustainable production will help protect the atmosphere, mountains, and oceans.

Submission ID: 116

The CIRCULAGRIS Project for Developing Metrics for Circularity and Sustainability in Italian Agri-Food Systems

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Abstract

The agricultural sector, a leading sector in Italy, is crucial for various EU sustainability initiatives and Circular Economy (CE) integration. However, evaluating the sustainability of specific CE practices is essential beyond mere circularity. Scholars stress the need for assessing sustainability impacts at both company and inter-firm levels, often using life cycle-based assessment methodologies, although further development is necessary for CE practices assessment. The CIRCULAGRIS project aims to understand the relationship between circularity and sustainability in the agricultural sector, thus identifying metrics and exploring the impact of circular practices.

Methodologically, the project encompasses several key approaches: identifying circularity assessment methods and indicators through systematic literature review, modelling circular systems within three key supply chains in Italy (wine, olive oil, bread/pasta), applying and testing assessment methods to these models, developing a comprehensive life cycle-based assessment framework for all sustainability dimensions, and assessing individual sustainability aspects using life cycle assessment, life cycle costing, and social life cycle assessment. Comparative and scenario analyses will be used to understand how circularity affects sustainability.

Expected results include the development of a framework for assessing the sustainability implications of the three identified supply chains, creating knowledge about applying life cycle-based methodologies within circular supply chains, identifying circularity assessment methodologies tailored to the agri-food sector, establishing an approach linking circularity and sustainability assessment to guide decision-makers, and identifying best practices for structuring supply chains considering sustainability impacts.

In conclusion, whilst CE is a priority for EU sustainability initiatives, its implementation may not always guarantee enhanced sustainability, especially in sectors like agri-food, which is vital for meeting human needs. This research seeks to fill existing gaps by providing methodological tools to assess circularity and sustainability in agri-food supply chains, thus allowing stakeholders to determine if their circular practices indeed lead to greater sustainability compared to linear approaches.

Contribution to SDGs and related targets: SDGs 2 and 12 + targets: 12.3, 12.4, 12.5. Relation to the topic of the Conference: *Offering methodological instruments for evaluating circularity and sustainability within agri-food supply chains*.

Submission ID: 122

Harmonising Sustainability: Steering Bioeconomy-Sustainable Development Goal Interactions and Influences in Europe

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Abstract

Despite facing unprecedented challenges, countries around the world are leveraging the 2030 Agenda and its 17 Sustainable Development Goals (SDGs) as a framework for navigating poly-crisis and building a more resilient and sustainable future. One promising solution to push for progress in this endeavour is transitioning towards a bioeconomy that utilises renewable resources and low-carbon value chains to meet rising food, energy, and materials demands. Recognising the bioeconomy's potential to catalyse a greener, fairer, and more prosperous future, the United Nations Food and Agriculture Organization (FAO) developed a comprehensive blueprint for a sustainable bioeconomy aligned with the SDGs. This indicator framework, comprised of ten principles and twenty-four criteria, provides a monitoring tool for countries to track and guide their transition towards a more sustainable bioeconomy. As a result, a growing number of countries have pledged to endorse this transition, committing to bioeconomy strategies.

While not inherently circular nor sustainable, the bioeconomy's interactions with SDGs, and vice versa, are complex. Synthesising insights from recent SDG and bioeconomy research and established frameworks, we employ a holistic approach to navigate this complex nexus. Combining correlation analyses, transfer entropy, and network analyses to reveal interactions, we further draw on literature and content analysis of policy gaps for qualitative insights. Exploring the European context, we updated the unified SDG database, developed a bioeconomy database aligned with the FAO framework, and used relevant bioeconomy policy strategies for the analysis. While initially intended as mutually supportive, the bioeconomy-SDG nexus is characterised by synergies and trade-offs. The bioeconomy framework incorporates the 2030 Agenda to guarantee a sustainable transition. Nonetheless, our analysis reveals a balanced influence, with both positive and negative interactions of similar magnitude. However, SDGs have a significant influence on the bioeconomy, with the positive influence notably outweighing the negative ones. This influence varies significantly across national contexts, shaping diverse network structures, which dilute at the European scale. Given this variation in the significance of interactions across different countries, tailoring bioeconomy transitions and solutions to each national context becomes crucial. Moving beyond broad principles and goals, a granular analysis of BE-SDG interactions, examining individual criteria and target interactions, reveals an intensified and diversified share of directed synergies and trade-offs. Further contributing to this complexity, we observed an unequal prioritization of certain SDGs over others in policy strategies, neither reflecting actual interaction patterns nor urgencies for progress in the respective goals, e.g., emphasis on environmental SDGs in the European strategy, while national strategies lean towards economic SDGs. This selective focus calls for a more balanced approach, ensuring inclusive progress towards all SDGs and unlocking the full potential of the bioeconomy-SDG nexus by leveraging synergies and minimizing trade-offs to harmonize both sustainability initiatives.

Submission ID: 163

Unraveling the Role of Retailers in Shaping the Circular Economy: Insights from Digital Innovations and Sustainability Initiatives

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Abstract

The retail industry, a major player in the global economy, is undergoing significant innovation driven by digitalization and Industry 4.0. The technological transformation in the market, accelerated during the COVID-19 crisis, underscores the crucial role of retailers in shaping the circular economy. While retailers are adopting digital technologies like virtual reality, artificial intelligence, and data analytics to engage customers, their potential role in enhancing sustainability in emerging economies remains largely unexplored. The present study adopts an explorative inductive design through data from 10 in-depth interviews with retailers involved in circular economy initiatives and 20 circular consumers. In this article, we journeyed to unravel the intricate relationship between retailers' digital technology-based resources and consumers´ circular behavior, delving into the capabilities required by retailers to implement digital technologies successfully, and generating a competitive advantage from circular economy-based business models. The study suggests that circular economy programs, such as buyback programs, reselling through retailer platforms and C2C resell platforms, benefit sustainable brands, and retailers by reducing costs, creating new revenue streams, improving efficiency, and enhancing customer engagement, and at the same time contributes to resource conservation, lower production costs and reduced environmental impact through closing the loops of materials (Euromonitor, 2024). This research provides valuable insights to both scholars and practitioners, particularly in understanding consumer behavior throughout the lifecycle of remanufactured, reused, upcycled, and recycled products.

SDG+Target: 12.5 and 12.A This contribution relates to the topic of the conference theme of "Linking Futures of Mountain and Ocean," as it addresses sustainability as a way of living through the diffusion and consumer adoption of circular business models in emerging economies like Colombia. In particular, the proposed contribution relates to track 5c Production, consumption, and innovation – Circular Economy, as it contributes to the areas of circular business models and consumer perspectives and roles in CE.

Full Papers

Submission ID: 19

Factors Affecting the Sustainability Assessment of Circular Bio-Based Building Materials: A Literature Review

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Abstract

Circular bio-based building material (CBBM) adoption is a potential strategy to mitigate the climate impact of the construction industry and to transform the sector into a circular model. The sustainability assessments (SA) of CBBMs, especially at the building scale, are vital to providing a solid basis for selecting CBBMs. However, there is still a lack of these SAs, implying that they are affected by various factors. Identifying and addressing these factors is vital to promoting the widespread implementation of these SAs. This study employs systematic and bibliometric approaches to review the state-of-the-art of existing studies. The result indicates that studies investigating factors affecting the SAs of CBBMs are hardly found. All 35 collected publications focus on examining the factors affecting the implementation of SA methods, mostly life cycle thinking methods, in the construction industry. Furthermore, this study also includes 45 articles that examine the factors affecting sustainable construction and green building development. The content analysis identifies lists of 24 barriers and 26 drivers that potentially affect the SAs of CBBMs. These factors provide a concrete basis for further investigations on their impacts on SAs of CBBMs, which may assist policymakers, practitioners, and scholars in taking appropriate measures to boost these SAs' implementation and also CBBM use in the construction industry.

Keywords. *Circular bio-based building materials, Circular construction, Sustainability assessment, Factors affecting, Barriers, Drivers*

Introduction

The construction industry accounts for 35% of energy consumption and is responsible for 38% of greenhouse gas (GHG) emissions globally (United Nations Environment Programme, 2020). The industry is also widely known as a natural resource-intensive sector since only material needed for constructing buildings and infrastructure in developing countries accounts for 50% of the total virgin natural resources extracted for material purposes in the world (De Wit *et al.*, 2018). Furthermore, the amount of wasted materials in this industry is up to 15% and is projected to continue increasing (United Nations Environment Programme, 2020). Therefore, this industry has detrimental impacts on the environment, economy, and society, highlighting the need to take action to overcome these impacts.

To mitigate the impacts of the construction industry, numerous solutions have focused on mitigating the impacts attributed to the operational phase of buildings. For instance, improving airtightness, using active shading and efficient lighting systems, etc., along with transitioning to renewable energy sources, are reported to cut off GHG emissions during this phase (Cabeza and Chàfer, 2020). However, the impacts of a building are not only attributed to the use phase since only embodied GHG emissions linked to the use

of building materials can contribute up to 50% of its life cycle emissions (Enkvist *et al.*, 2018). It suggests that along with targeting the use phase, initiatives and solutions need to focus on reducing impacts associated with other phases, especially the embodied impacts of materials.

It is worth noting that most embodied GHG emissions from buildings are linked to the consumption of traditional building materials, especially cementitious materials (Ahmed *et al.*, 2021) and steel (Tian *et al.*, 2013). Indeed, the production of cement is responsible for up to 5% of global GHG emissions (Ahmed *et al.*, 2021), while that figure for the steel industry is also around 4-5% (Tian *et al.*, 2013). This highlights the need for transitioning to the use of environmentally friendly materials to loosen the dependence on conventional, high-impact materials in the construction industry. In this context, increasing the use of circular bio-based building materials (CBBMs) stands out as one of the most coherent solutions. CBBMs are referred to as "*materials wholly or partly derived from renewable biological origins, or by-products and biowaste of plant and/or animal biomass that can be used as raw building materials and decorating items in construction, in their original forms or after being reprocessed*" (Le *et al.*, 2023, 2024). It should be mentioned that the form, size, composition, and other characteristics of CBBMs are diverse. However, Le *et al.* (2023) group them into three main categories: circular bio-based insulation materials (e.G, straw bales, straw boards, or hemp-based materials like hurds, hempcrete, etc.), circular bio-based cementitious materials (e.G, concrete that partially replaces cement with rice husk ash, etc.), and indoor-use CBBMs (such as bio-based biocomposite made from bio-waste and by-products, etc.). From the definition and examples of CBBM, it can be seen that the production of CBBMs can foster an innovative waste management approach relying on circular economy strategies such as recycling, reusing, reducing, and repurposing biowaste streams (Kirchherr and Piscicelli, 2019; Le *et al.*, 2023). Hence, using these materials can not only help mitigate embodied GHG emissions but also assist in transitioning the construction industry to a circular model and exploit benefits from the valorisation of by-products and biowaste streams from other sectors, such as forestry, agriculture, food, and even municipal solid waste (Le *et al.*, 2023; Rabbat *et al.*, 2022).

Nonetheless, since CBBMs are mostly new and emerging, their contribution to the sustainable built environment needs to be better investigated and documented to convince the stakeholders in the construction industry to uptake them. To this end, assessing the sustainability of these materials is vital. However, there is still a lack of studies evaluating the sustainability of CBBMs, encompassing environmental, economic and social performance, as well as the comprehensive sustainability at the building scale (Le *et al.*, 2024). This implies that there are factors affecting the assessment of the sustainability of these materials. A better understanding of these barriers and drivers is crucial to supporting scholars, practitioners, and especially decision-makers to take appropriate actions to promote the sustainability assessments of CBBMs, contributing to promoting their use in the construction industry. However, the literature shows that studies investigating the factors affecting the sustainability assessment of CBBMs or even bio-based building materials (BBMs) in a general sense are hardly found. This highlights the need to conduct a literature review study to shed light on this aspect and identify potential affecting factors to assist future empirical investigations on barriers to and/or drivers for the sustainability assessments of CBBMs or BBMs in the construction industry.

To fill the current gap, this study aims to (1) in-depth review the state-of-the-art of research on the sustainability assessments of buildings in general and CBBMs in particular, and (2) identify potential factors affecting, i.e., barriers to and/or drivers for the sustainability assessments of CBBMs. As such, this study can contribute to the body of knowledge for research on barriers to and drivers for sustainability assessments of

buildings with specific attention to those using CBBMs and BBMs. Furthermore, the identified barriers and drivers in this study can inform scholars who investigate the sustainability assessment of CBBM, supporting the widespread implementation of these assessments in the construction industry. The results of these assessments can ease barriers to CBBM adoption, such as the lack of information regarding environmental impacts and the perception of stakeholders about the high cost of these materials (Le *et al.*, 2023), this study can also contribute to encouraging stakeholders to use these materials. Therefore, this study can contribute to achieving Sustainable Development Goals 12 (indicators 12.2, 12.5, 12.6, and 12.8) and 13 (indicator 13.3).

Methodology

This study applies a combination of quantitative and qualitative research approaches, including three complementary methods, namely bibliometric, systematic, and content analysis. Bibliometric analysis can be used to evaluate published data, measure text and data sets regarding affiliation, authorships, etc., or illustrate the correlation between publications associated with a specific research topic (De Bellis, 2009; Fetscherin and Usunier, 2012). This approach can also support evaluating, describing, and monitoring the state of a specific field over time or carrying out meta-analyses to identify the critical elements and underlying theoretical frameworks of a research area (Fetscherin and Heinrich, 2015). Meanwhile, a systematic approach can provide a structured investigation of the existing literature to answer particular research questions, synthesise the best evidence, and widely disseminate these findings (Zumsteg *et al.*, 2012). Finally, content analysis is the best method to gain deep insights into study constructs and their interactions (Homrich *et al.*, 2018). Therefore, this method can allow the identification of barriers to and/or drivers for the sustainability assessments of CBBMs. Furthermore, this study is conducted based on the Preferred Reporting Items for Systematic Reviews and MetaAnalyses guidelines (Page *et al.*, 2021) to ensure the robustness, consistency, and transparency of the findings. Following this approach, this study's research methodology comprises three steps, as shown in Fig. 1.

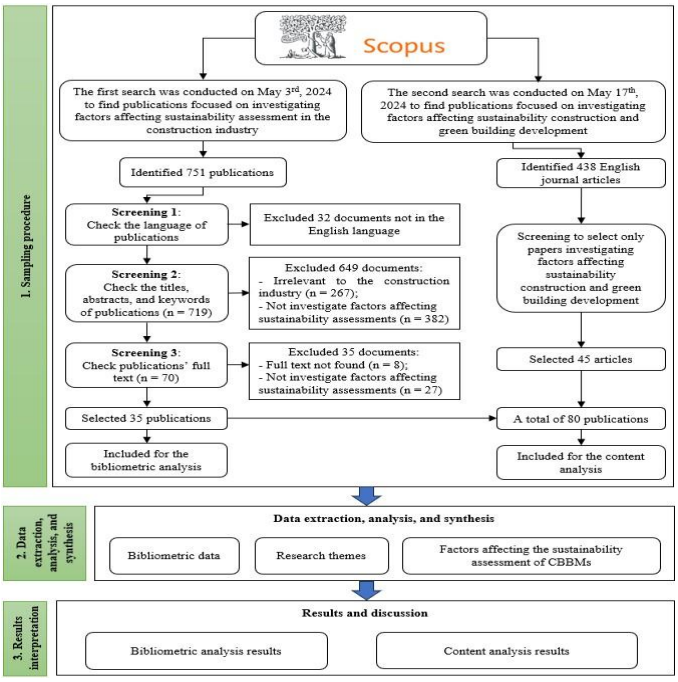

Figure. 1. Research methodology

Sampling Procedure

The sampling procedure starts with the establishment of search strategies and the selection of the scientific database. Firstly, the search query is formed by three title record fields, as follows:

(1): ("driver* for" OR "barrier* to" OR "factor* affect*" OR "enabler* for" OR "factor* influ*" OR "barrier* in*" OR "contractor perspectives" OR "client perspectives" OR "user perspectives" OR "architect perspectives" OR "challenges of");
(2): ("sustainability assessment*" OR "sustainable assessment" OR "life cycle assessment" OR "life cycle cost*" OR "social life cycle assessment" OR "life cycle sustainability assessment" OR "circularity assessment*" OR "energy* analysis" OR "environmental impact assessment" OR "social impact assessment" OR "economic sustainability assessment*"); and
(3): (building OR construction).

These three fields are connected by the "AND" operator to search for "Title-Abstract-Keywords" of existing publications in the Scopus database. This combination can assist in identifying all papers focused on investigating the factors affecting, i.e., barriers to and/or drivers for, the sustainability assessments in the construction industry from the existing literature in the targeted scientific database. Indeed, in the first field, all keywords like factors affecting, barriers to, drivers for, and their thesaurus words are included. Since the factors affecting the sustainability assessment are analysed from stakeholders' perspectives (Kwofie *et al.*, 2020; Tokbolat *et al.*, 2019), these keywords are included in the search query to avoid missing relevant publications. Meanwhile, the second field mentions sustainability assessment, or sustainable assessment in general, and the assessments of the three sustainable pillars (economic, environmental, and social), as well as several typical assessment methods that can be used for assessments. This is because, in the context of CBBMs, life cycle thinking tools, especially life cycle assessment and energy performance assessments, are the most commonly applied methods (Le *et al.*, 2024). Therefore, the inclusion of these keywords in the search query can maximise the number of relevant studies. Meanwhile, in the third field, no keywords related to CBBMs, BBMs, or even non-conventional building materials (e.G, low-carbon, alternative, green, wood, bamboo, or sustainable building materials) are included to avoid narrowing down searched results since these terms may not always be included in the title, abstract, and keywords of the previous studies.

In order to shed light on whether any research on evaluating factors affecting the sustainability assessments of CBBMs existS, this study considers not only journal articles but also grey literature, including book chapters, books, conference papers, notes, and others. The search was conducted on May 3rd, 2024, with no filters related to the time frame or types of publications, which helped to retrieve 751 publications. These publications were first screened to exclude those not written in English (n = 32), and therefore, the 719 remaining publications were screened to eliminate documents irrelevant to the construction industry (n = 267) and not investigate factors affecting sustainability assessments (n = 382). The remaining 70 documents were then screened using the eligibility criteria: "The publication investigated factors affecting, i.e., barriers to and/or drivers for, the assessments of at least one sustainable pillar of either CBBMs or buildings in general". The selection of this criterion was prompted by uncertainty regarding the existence of research evaluating the factors affecting the practice of sustainability assessment of CBBMs or even BBMs. Additionally, it can be considered that this practice

may be affected by the same factors affecting sustainability assessments of buildings in general. Due to eight documents not being accessible, the full text of 62 publications was screened to exclude 27 that did not fulfil eligibility criteria, i.e., 35 publications were included.

It should be highlighted that no study among these 35 publications is dedicated to investigating factors affecting sustainability assessments of CBBMs or BBMs. Therefore, these publications are appropriate for the bibliometric analysis to unveil aspects of the research on factors affecting sustainability assessments in the construction industry in general. Furthermore, a preliminary evaluation shows that these publications mostly researched barriers to sustainability assessment, i.e., lacking studies investigating drivers for this practice. Therefore, these documents may not be enough for the content analysis to identify potential affecting factors, especially drivers, for the practice of assessing the sustainability of CBBMs. Meanwhile, sustainability assessment is very important for achieving sustainability in the construction industry (Ness *et al.*, 2007). Meanwhile, getting credit for the whole LCA for buildings is important to achieving a green building (LEED) certificate (Pai and Elzarka, 2021). Therefore, the factors affecting sustainability assessment in the building sector in general and for CBBMs, in particular, may be coherent with those that affect sustainable construction and green building development. It should be highlighted that although the two terms “sustainable construction” and “green building” are often used interchangeably, they are distinct in some specific aspects (Kibert, 2016). Indeed, green buildings are defined as “buildings that are designed, constructed, and operated to boost environmental, economic, health, and productivity performance over non-green buildings” (US Green Building Council, 2003). This means that green building is more about the management of finished products, i.e., buildings, to reduce their negative impacts. Meanwhile, sustainable construction is defined as “a way of designing and constructing buildings that support human health (physical, psychological, and social) and which is in harmony with nature, both animate and inanimate” (Hendriks, 2001). Others defined sustainable construction as “the contribution of construction to sustainable development” (Pitt *et al.*, 2009). These imply that sustainable construction focuses more on the process of using natural resources to maintain an ecological balance than on finished buildings and their impacts, as in the green building development practice.

To identify relevant studies investigating factors affecting sustainable construction and green building development, a supplement search was conducted on the Scopus database on May 17th, 2024, using the search query: (“driver* for” OR “barrier* to” OR “factor* affecting”) AND (“sustainable building” OR “sustainable construction” OR “green building”). Since this is a mature research topic with many relevant papers that can be found, this study considers only peer-reviewed journal articles written in the English language for content analysis. A total of 438 articles were screened using the inclusion criterion “the publication investigates either barriers to or drivers for sustainable construction or green building development”. This helped to identify 45 journal articles, which were then used for only the content analysis, i.e., they were not included in the bibliometric analysis.

Data Extraction, Analysis and Synthesis

Firstly, metadata for bibliometric analysis, including abstracts, references, citation indexes, authors, institutions, countries, etc. (Carvalho *et al.*, 2013), is extracted from the Scopus database. These data sets are then analysed using Microsoft Excel and the VOSviewer tools, as well as the Biblioshiny R application.

Particularly, the VOSviewer tool is used to elaborate bibliometric networks to illustrate correlations among the analysed data, for instance, the co-occurrence of keywords (Cobo *et al.*, 2012). Since keyword data in Scopus is not always consistently harmonised, it is necessary to develop a thesaurus file to combine keywords with the same meaning (Van Eck and Waltman, 2021). Meanwhile, the Biblioshiny R application exploits bibliometric data to visualise the evolution of the research topic and develop maps to illustrate the scientific production of authors' countries.

Secondly, data regarding affecting factors, i.e., barriers to and/or drivers for the sustainability assessment in the construction industry, is gathered, synthesised, and managed using Microsoft Excel software through deep content analysis. It is worth noting that only factors that suit the context of CBBMs are considered potential affecting factors in the sustainability assessment of these materials. *2.3. Results reporting*

The results of this study are grouped into two macro-categories: a) Bibliometric analysis and b) Content analysis. Relevant subsections of this paper are therefore formed to communicate the results accordingly.

Results and Discussion

Bibliometric Analysis

Evolution of the research on sustainability assessments of CBBMs.

The evolution of the research topic on sustainability assessments of CBBMs in the construction industry is reflected in Fig. 2. As shown in the figure, before 2013, the concept of "investigating factors affecting the sustainability assessment in the construction industry" was very faded and fresh. Indeed, before 2013, only one study by Sterner in 2000 highlighted some factors affecting the utilisation of life cycle costing (LCC) to assess economic sustainability in the building sector (Sterner, 2000). From 2013 onwards, at least one publication on this topic was published annually, except for the year 2016. The most productive years were 2021, 2022, and 2023, with a peak of five studies published each year. Generally, it can be seen that this research topic started gaining much attention from scholars from 2018 onwards, as since then 80% of the collected publications have been published.

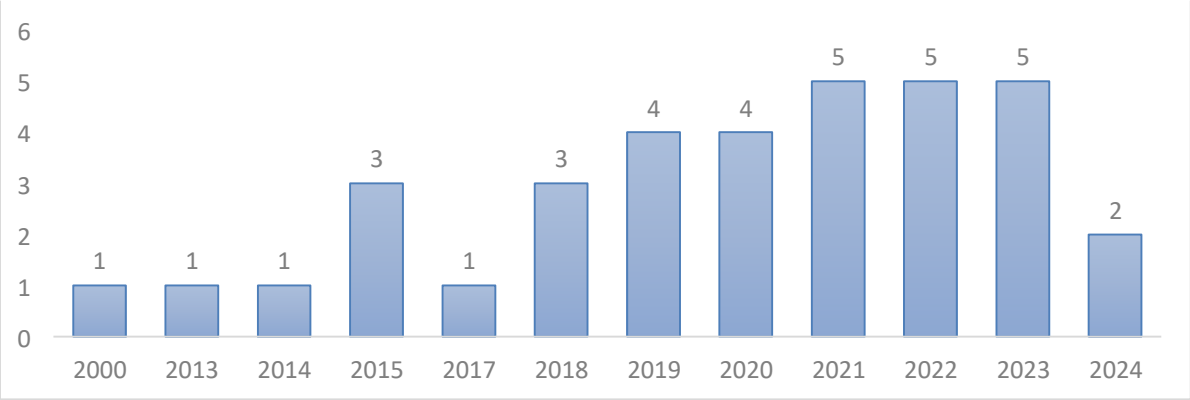

Figure 2. Year-base graph of literature.

Source-based analysis.

The source-based analysis of the collected publications is conducted using the Biblioshiny R application and is presented in Fig. 3. Generally, the 35 inventoried studies have been published in various sources (n = 26), including not only journals but also conference proceedings and book chapters. Among these sources, the "IOP Conference Series: Earth and Environmental Science" is the most productive, with four publications, followed by the Built Environment Project and Asset Management journal and Environmental Footprints and Eco-design of Products and Processes book series with three documents for each. It should be highlighted that, of the 35 collected publications, 21 are journal articles, while the remaining publications are grey literature, with 10 conference papers and four book chapters.

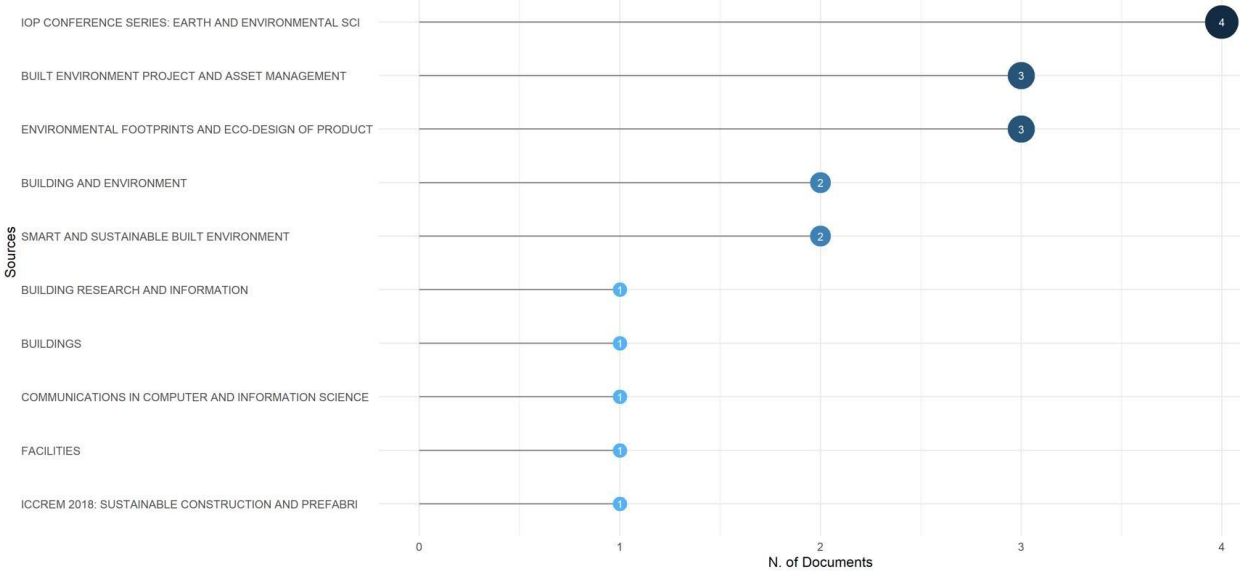

Figure 3. Most relevant sources of the collected publications

Co-occurrence network analysis.

The correlation among the most frequent keywords is visualised using the VOSviewer tool to evaluate the research pattern in the research topic. To this end, a thesaurus file is prepared to combine keywords with the same meaning (Van Eck and Waltman, 2021). For instance, "life cycle assessment", "life cycle assessment (LCA)", "life cycle analysis", and "LCA" have been merged into a single keyword "life cycle assessment". Likewise, "life cycle costing (LCC)", "lifecycle costing", and "LCC" are replaced by "life cycle costing". The thesaurus file is provided in the appendix (Table A1).

From the 35 collected documents, there are a total of 106 author keywords. After applying the thesaurus file, the number of keywords is reduced to 70, and their occurrence map is presented in Fig. 4. In this map, the strength of the connection between the nodes (keywords) is indicated by the thickness of the lines, and it is determined by counting the number of articles in which the two keywords appeared together. Shorter distances signify closer relationships between nodes, which are shown in their relationship and the similarity of their themes (Le *et al.*, 2023).

The most frequently occurring keywords are “life cycle costing” (n = 14), “life cycle assessment” (n = 12), and “barriers” (n = 8). These keywords are followed by “building information modelling (BIM)” (n = 7), “construction industry” (n = 6), and “sustainability” (n = 5). These findings highlight that most of the collected publications focused on investigating the barriers to the implementation of life cycle costing (LCC) and life cycle assessment (LCA). This also suggests that research on economic and environmental sustainability in the construction industry has drawn more attention from researchers worldwide than social or comprehensive sustainability in the construction industry. Furthermore, research on factors affecting the integration of BIM and life cycle thinking tools, especially LCA and LCC, has also arisen as the most frequently researched direction. On the other hand, the absence of the “driver” term in these 106 keywords may imply a lack of studies examining the driving force behind the sustainability assessment practice in the sector.

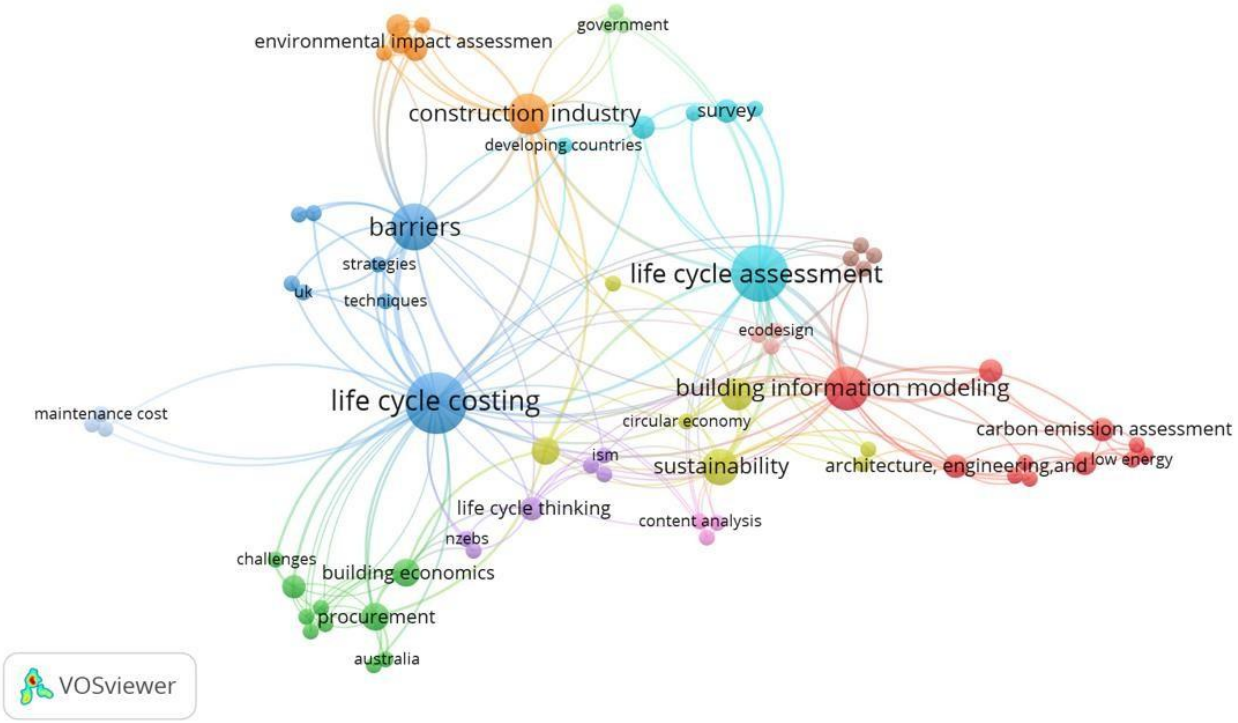

Figure 4. Keywords co-occurrence in the collected publications

Countries’ production

Based on the affiliations of contributing authors, the Biblioshiny R application generated a geographic heat map (Fig. 5) depicting the distribution of collected papers across different countries. The map illustrates an interactive method for determining the contribution of each country; countries with the lowest and highest densities of published articles are indicated by colour ranges ranging from light blue to deep blue. Malaysia and the USA are the most contributing countries, with 16 publications each, followed by Australia (n = 15), the UK (n = 12), Italy (n = 10), etc. Overall, this geographic distribution suggests that the research on evaluating factors affecting sustainability assessment in the construction industry has attracted attention from researchers globally; the majority of the collected publications are

contributed by scholars in developed countries. Otherwise, it is hardly found the contributions of researchers from the most vulnerable countries to climate change, especially sea-level rise, such as Bangladesh, Vietnam, etc. (Kulp and Strauss, 2019). This finding highlights the need for carrying out research that considers the factors affecting the sustainability assessment of buildings in general and CBBMs in particular.

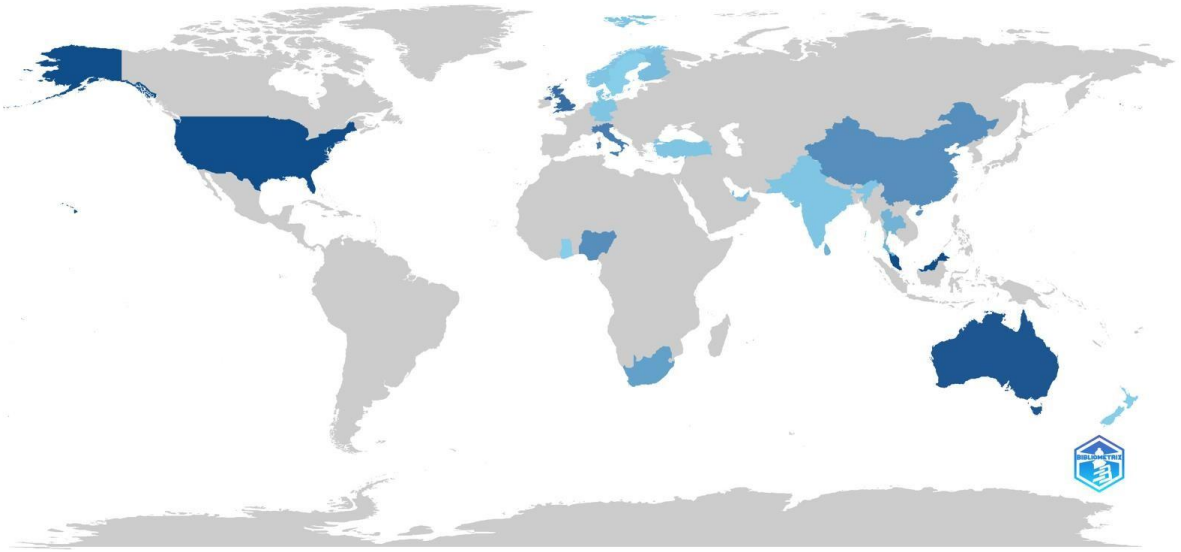

Figure 5. The geographical distribution of the collected publications

Content Analysis

This section categorises the collected publications' research themes to identify the most commonly researched direction. After that, the well-documented barriers to and drivers for the sustainability assessment in the construction industry are identified and provided based on the results from the content analysis of the collected sample. These barriers and drivers might be considered as potential factors affecting the sustainability assessment of CBBMs. Furthermore, this result can facilitate future studies investigating barriers to and/or drivers for the sustainability assessment of CBBMs, since using wellknown factors to develop a questionnaire survey can facilitate respondents to respond easily (Chan *et al.*, 2018).

Categorisation of research themes.

The research themes of the collected publications are grouped into five groups, as provided in Table 1, according to the assessment methods that these documents investigated. Among these five groups, the first group is the most dominant, with 15 studies examining the barriers and, to a lesser extent, the drivers for implementing LCC in the construction industry. This is followed by the second group, with eight studies identifying the factors affecting environmental sustainability assessment using LCA. Meanwhile, only three studies investigate affecting factors in the evaluation of two sustainable dimensions (n = 2) or comprehensive sustainability (n = 1) using life cycle thinking tools (LCC, LCA, and LCSA). Since the adoption of BIM for sustainability assessment purposes in the building sector is affected by various factors, five studies in the fourth group are dedicated to identifying these factors. Of these five, four are related to the

integration of BIM and LCA (n = 3) and LCSA (n = 1). Finally, the last group comprises studies exploring barriers to environmental impact assessment (n = 2), sustainability assessment methods (n = 1), as well as energy and carbon modelling (n = 1).

The above findings confirm the argument in the bibliometric analysis that most of the collected studies focus on the implementation of LCC and LCA for assessing sustainability in the construction industry. Furthermore, Table 1 demonstrates that no studies specifically investigate factors affecting the sustainability assessment of CBBMs or BBMs, despite the importance of these assessments in promoting the use of these materials. This highlights the need to conduct studies to fill this gap and promote the widespread implementation of sustainability assessments of CBBMs and the adoption of these materials, which can contribute to mitigating climate and other environmental impacts of the construction sector as well as exploiting the tremendous benefits of valorising biowaste.

Table 1. Categorisation of the research themes in the collected sample

No.	Research aims	Source	Methods used	Country
Group 1: Studies on factors affecting the implementation of LCC of CBBMs in the construction industry				
1	Investigating the challenges of LCC	[1]	Questionnaire survey	Malaysia
2	Investing factors affecting the use of LCC	[2]	Questionnaire survey	Sweden
3	Investigating barriers to LCC	[3]	Questionnaire survey and interview	Sri Lanka
4		[4]	Questionnaire survey	Malaysia
5		[5]	Questionnaire survey	Malaysia
6		[6]	Questionnaire survey	Nigeria
7		[7]	Questionnaire survey	China
8		[8]	Questionnaire survey and semi-structured interview	The UK
9		[9]	Questionnaire survey	The UK
10		[10]	Questionnaire survey	Malaysia
11		[11]	Semi-structured interview	Sri Lanka
12		[12]	Literature review	Not applicable (N/A)
13		[13]	Questionnaire survey	India
14	Investigating LCC drivers for sustainable office buildings	[14]	Case studies analysis	Denmark
15	Determining the key obstacles and enablers for LCC	[15]	Questionnaire survey	Australia

No.	Research aims	Source	Methods used	Country
Group 2: Studies on factors affecting the implementation of LCA in the construction industry in general				
1	Challenges of LCA of buildings	[16]	Literature review	N/A
2	Investigating barriers to LCA	[17]	Questionnaire survey	Germany
3		[18]	Questionnaire survey	South Africa
4		[19]	Questionnaire survey	North America
5		[20]	Focus groups	Not specify
6	Challenges of integrating whole building LCA into the building project process	[21]	Questionnaire survey and interview	Worldwide
7	Challenges in developing a holistic whole-building LCA software tool	[22]	Questionnaire survey and interview	Worldwide
8	Enablers for facilitating LCA	[23]	Semi-structured interviews	Sri Lanka
Group 3: Studies on factors affecting the implementation of combined LCC and LCA, or life cycle sustainability assessment (LCSA) in the construction industry in general				
1	Examining the current challenges of performing LCA and LCC	[24]	Questionnaire survey and interview	Europe
2	Examining barriers to the adoption of LCC and LCA	[25]	Literature review and Delphi study	N/A
3	Challenges to implementing LCSA	[26]	Literature review	N/A
Group 4: Studies on factors affecting the integration of BIM and sustainability assessment methods in the construction industry in general				
1	Identifying the challenges of BIM and LCA integration	[27]	Literature review	N/A
2		[28]	Literature review	N/A
3		[29]	Literature review	N/A
4	Barriers to BIM-Based Life Cycle Sustainability Assessment	[30]	Questionnaire survey	North America, Europe, and Africa
5	Drivers for energy analysis towards a BIM-enabled information flow	[31]	Interview	Not specify

No.	Research aims	Source	Methods used	Country
Group 5: Studies on factors affecting the adoption of other sustainability assessment methods in the construction industry in general				
1	Exploring challenges of adopting sustainability assessment methods	[32]	Semi-structured interview	UAE
2	Barriers to environmental impact assessment	[33]	Questionnaire survey	Nigeria
3		[34]	Questionnaire survey	Nigeria
4	Challenges for energy and carbon modelling	[35]	Literature review	Hong Kong

Note: [1]: (Maisham *et al.*, 2021); [2]: (Sterner, 2000); [3]: (Sandaruwan *et al.*, 2021); [4]: (Zaki *et al.*, 2019); [5]: (Maisham *et al.*, 2022); [6]: (Opawole *et al.*, 2020); [7]: (Jin *et al.*, 2018); [8]: (Higham *et al.*, 2015); [9]: (Oduyemi *et al.*, 2014); [10]: (Altaf *et al.*, 2024); [11]: (Weerasinghe and Ramachandra, 2023); [12]: (Amini Toosi *et al.*, 2023); [13]: (Guru and Mohibullah, 2021); [14]: (Haugbølle & Raffnsøe, 2019); [15]: (Lim *et al.*, 2018); [16]: (Nwodo and Anumba, 2019); [17]: (Lützkendorf & Balouktsi, 2020); [18]: (Kwofie *et al.*, 2020); [19]: (Olinzock *et al.*, 2015); [20]: (Saunders *et al.*, 2013); [21]: (Thais Sartori *et al.*, 2022); [22]: (T Sartori *et al.*, 2022); [23]: (Amarasinghe and Hadiwattege, 2022); [24]: (Bruce-Hyrkäs *et al.*, 2018); [25]: (D'Incognito *et al.*, 2015); [26]: (Amini Toosi *et al.*, 2021); [27]: (Xue *et al.*, 2021); [28]: (Azizoglu and Seyis, 2020); [29]: (Samniang *et al.*, 2023); [30]: (Onososen and Musonda, 2022); [31]: (Mohammad Ahmad *et al.*, 2022); [32]: (Shibieka *et al.*, 2020); [33]: (Osuizugbo and Nnodu, 2023); [34]: (Osuizugbo *et al.*, 2024); [35]: (Pan *et al.*, 2017).

Potential barriers to the sustainability assessment of CBBMs.

The content analysis of the collected publications shows that the sustainability assessment of buildings is hindered by various factors, which can be considered potential barriers to the practice of assessing the sustainability of CBBMs.

Firstly, sustainability assessment is well-known as a data-intensive practice (Nwodo and Anumba, 2019); therefore, it has to face data and information-related barriers. Analysing the collected papers shows that the lack of needed databases and information is one of the most critical barriers hindering sustainability assessment, especially when using life cycle thinking tools, in the building sector (Samniang *et al.*, 2023; Sterner, 2000). Besides that, factors associated with the methodology, software, and calculation process have also been reported as obstacles to the practice. The complexity of sustainability assessment methods as well as supporting tools and software have been reported in previous studies as barriers to sustainability assessment practice (Altaf *et al.*, 2024; D'Incognito *et al.*, 2015; Sartori *et al.*, 2022). Existing studies also indicate that the lack of sustainability assessment methods and tools can hinder the practice of assessing sustainability in the construction industry (Amarasinghe and Hadiwattege, 2022; Sandaruwan *et al.*, 2021). Besides that, due to most sustainability assessment methods considering only the environmental aspect, they are less attractive to housing developers, affecting their utilisation to evaluate the sustainable performance in the sector (Nwodo and Anumba, 2019). Furthermore, since sustainability assessment methodologies, tools, and software are complex for building stakeholders, consistent metrics and guidance for practitioners are needed to overcome these complexities. Therefore, the lack of such metrics and guidance is reported as a barrier to conducting sustainability assessments (Altaf *et al.*, 2024; Amarasinghe and Hadiwattege, 2022; Lim *et al.*, 2018). Another difficulty in the process of assessing the sustainability of buildings can be attributed to the involvement of various stakeholders with different opinions (Sandaruwan *et al.*, 2021). Therefore, a model to communicate and share information among these stakeholders is essential to support the calculations. That is why previous studies highlight that the

lack of such a model hinders the practice of assessing sustainability in the construction industry (Amarasinghe and Hadiwattege, 2022; Amini Toosi *et al.*, 2021).

Secondly, similar to the implementation of other sustainable practices in the construction industry, the sustainability assessment of CBBMs is hindered by barriers associated with the government's role. Inadequate building codes, standards, and regulations that support the sustainability assessment or sustainable construction practices, as well as government policies, support, and incentives, have been acknowledged as the main barriers to the implementation of LCC and LCA for assessing economic and environmental sustainability in the construction industry in both developed and developing countries (Lützkendorf and Balouktsi, 2020; Sandaruwan *et al.*, 2021; Sterner, 2000). This is because of the highly cost-driven and conservative nature of the construction industry (Zhang and Canning, 2011), where sustainability goals are frequently disregarded without being regulated by the government (Williams and Dair, 2007). Meanwhile, lacking support and incentives means that the additional expenses associated with the sustainability assessment cannot be offset, affecting the engagement of stakeholders in this practice. Along with these barriers, the lack of sustainability assessment promotion by the government is reported as a barrier to assessing the sustainability performance of buildings (Altaf *et al.*, 2024; Osuizugbo and Nnodu, 2023). Similar to incentives, promotion is necessary to encourage stakeholders to conduct sustainability assessments (Osuizugbo and Nnodu, 2023). Furthermore, the adoption of methods like LCA to evaluate the sustainability of buildings even in developed countries is still lagging (Lützkendorf and Balouktsi, 2020), implying their novelty and difficulty for building professionals. Therefore, sustainability assessment training, especially for project staff, as well as demonstration projects and case studies, are needed to increase the knowledge and experience of stakeholders towards sustainability assessments, especially by using life cycle thinking tools. Because of this importance, previous studies have highlighted the lack of these aspects as barriers to sustainability assessments in the construction industry (Azizoglu and Seyis, 2020; Lützkendorf and Balouktsi, 2020; Onososen and Musonda, 2022).

Thirdly, the implementation of green innovation in a highly cost-driven and conservative industry like construction has to face cost- and risk-related barriers (Zhang and Canning, 2011). This is also true in the context of assessing the sustainability of buildings in general and CBBMs in particular. Particularly, higher investment costs and the risks of unforeseen costs are reported as critical barriers to assessing the sustainability of buildings (Osuizugbo and Nnodu, 2023; Samniang *et al.*; Sandaruwan *et al.*, 2021). This barrier also leads to clients' worry about profitability, which is also considered a barrier (Shibieka *et al.*, 2020). Besides that, the adoption of new methodologies to evaluate the sustainable performance of buildings may also face risks and uncertainties, and therefore, this factor has been identified as a barrier to sustainability assessment practice in previous studies (Oduyemi *et al.*, 2014; Onososen and Musonda, 2022; Osuizugbo and Nnodu, 2023). Along with cost and risk-related factors, the implementation of sustainability assessment may also prolong the design process, leading to the perception that extra time is being incurred, which becomes a main barrier hindering the practice (Kwofie *et al.*, 2020; Lützkendorf and Balouktsi, 2020; Opawole *et al.*, 2020).

Fourthly, the conservative nature of the construction industry may hinder the sustainability assessment of CBBMs. Indeed, this practice is considered an innovative approach to achieving sustainability in the construction industry, and due to the conservatism in the sector, stakeholders may be resistant to its implementation. For instance, previous studies reported this factor as the main obstacle to economic and

environmental sustainability assessments using life cycle thinking tools (Onososen and Musonda, 2022; Sterner, 2000). The resistance to the uptake of sustainability assessments may be due to the lack of awareness of sustainability assessment and its benefits among stakeholders in the sector and the lack of importance attached to sustainability assessment by senior management (Altaf *et al.*, 2024; Sandaruwan *et al.*, 2021). The underevaluation of the importance of the sustainability assessment practice by these actors will lead to their inadequate preparation for this practice, for instance, not organising training and development for their employees regarding the implementation of sustainability assessment methods (Maisham *et al.*, 2022; Thais Sartori *et al.*, 2022). This leads to the unfamiliarity of construction professionals with sustainability assessment and a lack of professional knowledge and expertise in sustainability assessment, hindering the practice in the construction industry (Opawole *et al.*, 2020; Osuizugbo and Nnodu, 2023; Sandaruwan *et al.*, 2021). All of these factors act as barriers to the sustainability assessment of CBBMs and, therefore, are collected and provided in Table 2.

Lastly, the sustainability assessment of CBBMs is also hindered by market-related barriers. After all, all activities in the market stem from customer needs. Implementing sustainability assessments of CBBMs in particular or building products in general is also determined by clients' interests and demands. Consequently, lacking interest from clients and market demand has been reported as a barrier to this practice (Maisham *et al.*, 2022; Olinzock *et al.*, 2015; Saunders *et al.*, 2013).

Although the collected publications refer only to sustainability assessment in the construction industry in general, the aforementioned barriers are also true in the context of assessing the sustainability of CBBMs. This is because the practice of assessing the sustainability of CBBMs is part of the sustainability assessment practice in the building sector in a general sense. A total of 24 potential barriers extracted from the collected sample are presented in Table 2.

Table 2. Potential barriers to the sustainability assessment of CBBMs

Code	Barriers	Source
B01	Inadequate building codes, standards, and regulations	[1-36]
B02	Inadequate government policies/support	[2, 4, 6-9, 11, 13, 15-18, 21-23, 25, 26, 32, 36-43]
B03	Lack of demonstration projects and case studies	[1-3, 14, 15, 18, 25, 28, 30, 33-35, 44-47]
B04	Lack of government incentives	[5, 7, 9, 10, 12, 15, 17-20, 22-30, 32-34, 37, 40, 43, 45-51]
B05	Lack of sustainability assessment education and training in higher education	[6, 7, 13-15, 17, 18, 22, 23, 28, 30, 31, 33, 36, 38, 41-43, 50, 52-54]
B06	Lack of sustainability assessment promotion by the government	[4, 15, 19, 22, 24, 32, 33, 36, 39, 55]

Code	Barriers	Source
B07	Lack of importance attached to sustainability assessment by senior management	[5, 6, 17, 27, 31, 34, 39, 55-57]
B08	Resistance to change	[2-6, 10, 15-18, 22, 23, 25-28, 30, 3234, 36, 39, 41, 43, 44, 46, 48, 50, 51, 53, 56, 58, 59]
B09	Limited knowledge of construction professionals with sustainability assessment	[4, 5, 9, 15, 23, 25, 27, 28, 30, 32, 33, 36, 43, 47, 48, 54]
B10	Inadequate employee training and development	[4, 7, 15, 17, 18, 22, 23, 28, 38, 48, 50, 52, 53, 60]
B11	Lack of professionals in sustainability assessment	[2-9, 11, 14-19, 21-29, 33, 38, 39, 41-43, 46, 48, 50, 54, 55, 57, 58, 61-63]
B12	Lack of needed databases and information	[2-10, 12, 13, 16, 17, 21, 23, 24, 30, 34, 36-41, 43-46, 48, 49, 55-58, 61, 62, 64, 65]
B13	Lack of awareness of sustainability assessment and its benefits	[4, 5, 8, 9, 12-19, 22-24, 26-28, 30-35, 37-39, 41, 43, 47, 48, 50, 51, 53, 55, 57, 59, 63]
B14	Lack of a model to exchange information and communicate between stakeholders to support the assessment	[4, 5, 15, 17, 23, 27, 29, 30, 32, 34, 36, 37, 43, 53, 54, 65]
Code	**Barriers**	**Source**
B15	Lack of consistent metrics and guidance for practitioners	[5, 9, 34, 37-39, 48, 56]
B16	Lack of interest from clients and market demand for sustainable products	[6, 7, 9, 12, 14, 15, 17-19, 21-23, 25, 27, 29, 30, 32-35, 38, 39, 41-43, 45, 48-53, 55, 57, 60, 63]
B17	Clients worry about profitability	[15, 59]
B18	Fear of higher investment costs and the risks of unforeseen cost	[3-10, 13-16, 18, 19, 21-30, 32-35, 3739, 41-43, 45-47, 49-52, 54, 59, 60, 63, 66]

Code	Barriers	Source
B19	Risks and uncertainties involved in adopting new methodologies	[4, 6, 12, 15, 19, 23, 26, 30, 32, 39-41, 43, 46-48, 51, 55, 65]
B20	Perception of extra time being incurred	[2, 3, 6-9, 14, 18, 19, 23, 32, 34, 38, 39, 41, 44, 45, 48, 49, 51, 52, 56-61, 63, 66]
B21	The complexity of supporting tools and software	[1, 10, 30, 32, 39, 60, 62]
B22	Lack of sustainability assessment methods and tools	[1, 5, 37, 48, 56, 57]
B23	The complexity of sustainability assessment methods	[5, 6, 10, 39, 44, 45, 48, 49, 52, 56, 58, 60, 61]
B24	Most assessment methods are less attractive to developers because of consider only the environmental aspect	[61, 67]

Note: [1]: (Azizoglu and Seyis, 2020); [2]: (Sterner, 2000); [3]: (Samniang *et al.*); [4]: (Osuizugbo and Nnodu, 2023); [5]: (Sandaruwan *et al.*, 2021); [6]: (Onososen and Musonda, 2022); [7]: (Lützkendorf and Balouktsi, 2020); [8]: (Kwofie *et al.*, 2020); [9]: (Opawole *et al.*, 2020); [10]: (D'Incognito *et al.*, 2015); [11]: (Jin *et al.*, 2018); [12]: (Oduyemi *et al.*, 2014); [13]: (Osuizugbo *et al.*, 2024); [14]: (Akcay, 2023); [15]: (Dalirazar and Sabzi, 2020); [16]: (Omopariola *et al.*, 2022); [17]: (Fathalizadeh *et al.*, 2021); [18]: (Zulu *et al.*, 2022); [19]: (Santana *et al.*, 2023); [20]: (Hoxha and Lecaj, 2022); [21]: (Abdelaal and Guo, 2021); [22]: (Chigozie Osuizugbo *et al.*, 2020); [23]: (Marsh *et al.*, 2020); [24]: (Agyekum *et al.*, 2019); [25]: (Azeem *et al.*, 2017); [26]: (Abu Bakar *et al.*, 2018); [27]: (Pham *et al.*, 2019); [28]: (Çivici and Özlük, 2020); [29]: (Deng *et al.*, 2016); [30]: (Nguyen *et al.*, 2017); [31]: (Karji *et al.*, 2020); [32]: (Hwang *et al.*, 2018); [33]: (Tokbolat *et al.*, 2019); [34]: (Sourani and Sohail, 2011); [35]: (Häkkinen and Belloni, 2011); [36]: (Wilson and Rezgui, 2013); [37]: (Amarasinghe and Hadiwattege, 2022); [38]: (Lim *et al.*, 2018); [39]: (Altaf *et al.*, 2024); [40]: (Amini Toosi *et al.*, 2023); [41]: (Assylbekov *et al.*, 2021); [42]: (Shen *et al.*, 2018); [43]: (Djokoto *et al.*, 2014); [44]: (Xue *et al.*, 2021); [45]: (Olinzock *et al.*, 2015); [46]: (Guribie *et al.*, 2021); [47]: (Masia *et al.*, 2020); [48]: (Maisham *et al.*, 2022); [49]: (Saunders *et al.*, 2013); [50]: (Maqbool *et al.*, 2023); [51]: (Yin *et al.*, 2018); [52]: (Thais Sartori *et al.*, 2022); [53]: (Dalirazar and Sabzi, 2022); [54]: (Awaili and *et al.*, 2020); [55]: (Zaki *et al.*, 2019); [56]: (Maisham *et al.*, 2021); [57]: (Higham *et al.*, 2015); [58]: (Bruce-Hyrkäs *et al.*, 2018); [59]: (Shibieka *et al.*, 2020); [60]: (T Sartori *et al.*, 2022); [61]: (Nwodo and Anumba, 2019); [62]: (Pan *et al.*, 2017); [63]: (Guru and Mohibullah, 2021); [64]: (Weerasinghe and Ramachandra, 2023); [65]: (Amini Toosi *et al.*, 2021); [66]: (Tam *et al.*, 2012); [67]: (Ding, 2008).

Potential drivers for the sustainability assessment of CBBMs.

Despite barriers hindering the sustainability assessment of CBBMs, many drivers can encourage stakeholders to assess the sustainable performance of these materials. Firstly, previous studies confirm that the government plays a determined role in promoting the practice of assessing sustainable performance in the construction industry. Indeed, statutory regulations and enforcement, as well as government mandates for assessing the sustainable performance of buildings, have been reported as the most important driving forces for implementing this practice in the construction industry (Marsh *et al.*, 2020; Sterner, 2000). Furthermore, government support and incentives such as tax reductions, low-interest loan schemes, etc., along with stronger incentives for green building certification, can be a catalyst to encourage stakeholders to implement sustainability assessments in their projects

(Amarasinghe and Hadiwattege, 2022; Marsh *et al.*, 2020). This is because government incentives can offset additional costs associated with the implementation of sustainability assessments. Meanwhile, stronger incentives in green building certification schemes can motivate the willingness of housing developers and their consultants to conduct these assessments to gain credits or scores towards the highest certification, for instance, LEED platinum. Additionally, more demonstration projects and case studies (Azizoglu and Seyis, 2020; Samniang *et al.*; Sterner, 2000) as well as fostering educational training (Omopariola *et al.*, 2022; Onososen and Musonda, 2022; Sterner, 2000) can illustrate sustainability assessments and equip practitioners with fundamental knowledge and skills to handle tasks during the assessment process. Therefore, these factors can change stakeholders' awareness and drive them to evaluate the sustainability of their projects, especially those using CBBMs.

In addition to governmental drivers, human-related forcing factors play a crucial role in promoting the sustainability assessment of CBBMs. The awareness of the public in general (Onososen and Musonda, 2022; Osuizugbo and Nnodu, 2023) and construction stakeholders (Abu Bakar *et al.*, 2018; Marsh *et al.*, 2020) of sustainability assessment, in particular, is vital to promoting their ecologic consciousness and their willingness to get involved in the practice of assessing the sustainable performance of their buildings (Opawole *et al.*, 2020; Samniang *et al.*, 2023). That is why these factors have been reported in previous studies as drivers for sustainability assessment in the construction industry. Furthermore, this practice is complicated due to the complexity of the assessment methodology and supporting tools. Thus, after all, if construction stakeholders, especially clients, are encouraged to conduct such assessments on their projects, they need professionals to carry out the assessment. As such, the knowledge and skills of personnel and practitioners from these industry stakeholders are highlighted as one of the key drivers to the successful implementation of sustainability assessments in the construction industry (Opawole *et al.*, 2020; Samniang *et al.*, 2023).

The practice of assessing sustainability in the construction industry may also be promoted by driving forces associated with assessment methods and supporting tools. Indeed, previous studies report that professionals and practitioners are more likely to carry out sustainability assessments if they perceive the ease of methods and tools (Samniang *et al.*, 2023). The same result is also reported in the previous studies if the availability of usable sustainability assessment methods and tools is increased (Samniang *et al.*, 2023). In addition, adequate databases and information can act as a catalyst for stakeholders to conduct sustainability assessments in the construction industry since this factor can accelerate the assessment process and ensure the accuracy and reliability of the results (Samniang *et al.*, 2023; Sandaruwan *et al.*, 2021).

Besides that, building-based drivers are also essential to promoting the sustainability assessment of CBBMs. After all, stakeholders, especially building owners, need to know the benefits linked to sustainability assessments of their buildings to decide whether to conduct those assessments. Carrying out sustainability assessments can inform decision-makers about the environmental hotspots that need to be addressed to improve the environmental sustainability of buildings. In other words, these assessments have the potential to reduce negative environmental impact, i.e., create positive impacts (Abdelaal and Guo, 2021; Sterner, 2000; Zulu *et al.*, 2022), and therefore, they can encourage stakeholders, especially those with high sustainability awareness and consciousness, to be incorporated. Besides that, these assessments can also bring benefits associated with energy-related factors, such as

improving the energy efficiency of buildings, reducing energy consumption, and, therefore, saving operational energy costs and the whole life cycle cost (Sterner, 2000; Tokbolat *et al.*, 2019; Zulu *et al.*, 2022). Also related to energy, if the energy price is increased, it also forces stakeholders to conduct sustainability assessments to identify approaches to lower energy consumption (Sterner, 2000; Tokbolat *et al.*, 2019; Zulu *et al.*, 2022). That is why energy-related factors are reported as an important driver for conducting sustainability assessments in the construction industry. Besides that, such assessments also help to achieve high-quality buildings in terms of improving occupant health, comfort, satisfaction, etc., since the assessment results can act as a basis for the building's quality improvement, especially during the design process (Samniang *et al.*, 2023; Sterner, 2000). If stakeholders perceive this benefit, they are more likely to be motivated to conduct sustainability assessments on their projects, including those using CBBMs.

The sustainability assessment of CBBMs can also be driven by internal organisational driving forces. Indeed, construction stakeholders are more likely to uptake such assessments in their projects if they are ready, for instance, in terms of technical preparation (Azeem *et al.*, 2017; Osuizugbo and Nnodu, 2023). The same likelihood can occur if they perceive that such practice can bring a good image and reputation (Abdelaal and Guo, 2021; Zulu *et al.*, 2022), as well as a competitive advantage and business opportunity for their companies (Abdelaal and Guo, 2021; Abu Bakar *et al.*, 2018), or align with their corporate social responsibility (Zulu *et al.*, 2022). Moreover, since the costs associated with the practice of assessing sustainability may increase the initial investment costs of projects, the adequate financial capacity of stakeholders can ensure that they can cover all these increased upfront costs, which can then be offset by the operational energy costs saved during the use stage of buildings. Consequently, this factor is a vital driving force for the successful promotion of the implementation of sustainability assessment in the building sector (Opawole *et al.*, 2020; Osuizugbo and Nnodu, 2023; Sandaruwan *et al.*, 2021).

Finally, the contribution of market-based drivers to successfully promoting the practice of assessing the sustainability of CBBMs should not be overlooked. Increasing client demand for sustainability assessments has been identified as critical for promoting this practice in the construction industry (Lützkendorf and Balouktsi, 2020; Opawole *et al.*, 2020; Sterner, 2000). This is understandable since the laws of supply and demand steer market movement. When the demand side increases, the supply side also needs to be more active in serving the clients' market and, therefore, boosting the practice of sustainability assessment in the sector. Regarding the consultants and contractors, if the contract and housing developers are required to carry out sustainability assessments, they are motivated to prepare technical aspects to carry out such assessments to meet compliance, contributing to the widespread implementation of such assessments in the industry (T Sartori *et al.*, 2022; Thais Sartori *et al.*, 2022). Moreover, stakeholders in the construction industry have a greater likelihood of evaluating the sustainability of their projects under peer pressure from other businesses (Onososen *et al.*, 2022; Song *et al.*, 2021), gaining marketing benefits (Amarasinghe and Hadiwattege, 2022; Darko *et al.*, 2017), as well as attracting premium consumers and achieving high returns from such practices (Assylbekov *et al.*, 2021; Marsh *et al.*, 2020; Zulu *et al.*, 2022).

The comprehensive content analysis of the collected publications identifies a list of 26 drivers for assessing sustainability in the construction industry that have drawn considerable attention from researchers and practitioners. They can be considered potential driving factors for the sustainability assessment of CBBMs and are presented in Table 3.

Table 3. Potential drivers for the sustainability assessment of CBBMs

Code	Drivers	Source
D01	Statutory regulations and enforcement	[1-22]
D02	Government support and incentives	[3, 8-10, 13-15, 17-21, 23-30]
D03	Government mandate	[2, 5, 9, 10, 12, 13, 15, 17, 19, 21, 26, 31-33]
D04	Peer pressure from other businesses	[15, 19, 29]
D05	Stronger incentives for sustainability assessment in green building certification schemes	[3, 5, 17, 28, 34]
D06	More demonstration projects and case studies	[1, 2, 14, 29, 35]
D07	Knowledge and skills of personnel and practitioners	[7, 9, 14, 18, 19, 21, 25, 26, 35, 36]
D08	Personal willingness to practice	[13, 15, 18, 19, 21, 26, 35, 37]
D09	Educational training	[2, 3, 13-15, 17-19, 21, 25, 28-31, 34, 37-40]
D10	Stakeholders' awareness of sustainability assessment	[3, 6, 9, 11, 15, 17, 18, 20-23, 25, 28, 30, 34]
D11	Public awareness of sustainability assessment	[3, 7, 9, 10, 13, 17, 19, 21, 26-29, 37, 41-43]
D12	Adequate needed databases and information	[3, 7, 13, 21, 24, 34, 35]
D13	Perceived ease of methods and tools	[15, 31, 35, 38]
D14	More usable sustainability assessment methods and tools	[3, 35]
D15	Attract premium consumers and achieve high returns	[12, 17, 28, 30, 31, 34, 40, 43, 44]
D16	Potential to reduce negative environmental impact/create positive impacts	[2, 3, 11, 16, 17, 30, 34, 40, 43, 45]
D17	Energy-related factors (e.G, energy efficiency, reduced energy consumption and cost, increased energy cost, etc.)	[2, 3, 12, 40, 44-47]
D18	Achieve high-quality building (e.G, improved occupant health, comfort, and satisfaction)	[2, 17, 19, 28, 30, 35, 44, 47]
D19	Good corporate image and reputation	[12, 16, 17, 22, 25, 28, 40, 47]
D20	Corporate social responsibility	[11, 12, 25, 28, 30, 40]
D21	Adequate financial capacity	[6, 7, 15, 18, 21, 24, 26, 41]
D22	Organisation readiness	[13, 15, 29, 41]
D23	Competitive advantage and business opportunity	[12, 16, 18, 30]
D24	Increasing client demand	[2, 5, 11, 14, 16-18, 20-22, 26, 30, 31, 34, 38, 40, 48]

Code	Drivers	Source
D25	Marketing benefits	[3, 30]
D26	Meeting contract and developers' requirements	[30, 31, 38]

Note: [1]: (Azizoglu and Seyis, 2020); [2]: (Sterner, 2000); [3]: (Amarasinghe and Hadiwattege, 2022); [4]: (Kwofie *et al.*, 2020); [5]: (Lim *et al.*, 2018); [6]: (Higham *et al.*, 2015); [7]: (Altaf *et al.*, 2024); [8]: (Amini Toosi *et al.*, 2023); [9]: (Siddiqui *et al.*, 2024); [10]: (Zhu *et al.*, 2023); [11]: (Van Nguyen, 2023); [12]: (Agyekum *et al.*, 2021); [13]: (Anzagira *et al.*, 2022); [14]: (Babalola and Harinarain, 2021); [15]: (Onososen *et al.*, 2022); [16]: (Abdelaal and Guo, 2021); [17]: (Marsh *et al.*, 2020); [18]: (Abu Bakar *et al.*, 2018); [19]: (Song *et al.*, 2021); [20]: (Häkkinen and Belloni, 2011); [21]: (Gan *et al.*, 2015); [22]: (Serpell *et al.*, 2013); [23]: (Shibieka *et al.*, 2020); [24]: (Sandaruwan *et al.*, 2021); [25]: (Maisham *et al.*, 2022); [26]: (Opawole *et al.*, 2020); [27]: (Xue *et al.*, 2021); [28]: (Assylbekov *et al.*, 2021); [29]: (Azeem *et al.*, 2017); [30]: (Darko *et al.*, 2017); [31]: (Thais Sartori *et al.*, 2022); [32]: (Maqbool *et al.*, 2023); [33]: (Deng *et al.*, 2016); [34]: (Bruce-Hyrkäs *et al.*, 2018); [35]: (Samniang *et al.*); [36]: (Nwodo and Anumba, 2019); [37]: (Onososen and Musonda, 2022); [38]: (T Sartori *et al.*, 2022); [39]: (Omopariola *et al.*, 2022); [40]: (Zulu *et al.*, 2022); [41]: (Osuizugbo and Nnodu, 2023); [42]: (Dalirazar and Sabzi, 2022); [43]: (Tam *et al.*, 2012); [44]: (Masia *et al.*, 2020); [45]: (Mohammad Ahmad *et al.*, 2022); [46]: (Haugbølle and Raffnsøe, 2019); [47]: (Tokbolat *et al.*, 2019); [48]: (Lützkendorf and Balouktsi, 2020).

Conclusion

The sustainability assessment of CBBMs is vital to promote the widespread adoption of these materials in the construction industry and to shed light on their contribution to a sustainable built environment. However, there is still a lack of such assessments (Le *et al.*, 2024), implying that this practice may be affected by various factors. Identifying and understanding these factors is crucial to successfully promoting the practice of assessing the sustainable performance of CBBMs in the construction industry.

This study applies a systematic approach to review the state-of-the-art of studies investigating factors affecting sustainability assessments in the construction industry in general and for CBBMs in particular. From that thorough review, the popular research themes, barriers to, and drivers for the sustainability assessment practice are identified and discussed. Firstly, to shed light on whether studies investigating factors affecting the sustainability assessment of CBBMs exist, this study considers not only journal articles but also the grey literature identified from the Scopus database. The results show that no study in the context of CBBMs could be found in the existing literature. On the other hand, most of the identified publications focused on examining barriers to the assessment solely of economic or environmental sustainability in the construction industry by using LCC and LCA. There is still a lack of research on drivers for sustainability assessments, especially comprehensive sustainability, i.e., including all three sustainable dimensions, in the construction industry.

Given the scarcity of studies considering the affecting factors, especially drivers for the sustainability assessment of CBBMs, this study takes into consideration publications examining factors affecting either sustainable construction or green building development. Through the comprehensive content analysis of the collected studies, 24 barriers and 26 drivers for either sustainability assessment in the construction industry or sustainable construction and green building development are extracted. These barriers and drivers are considered potential factors affecting the practice of assessing the sustainability performance of CBBMs.

Generally, the findings of this study can contribute to the body of knowledge of research on investigating factors affecting sustainability assessment in the construction industry in general and for CBBMs in

particular. However, this study also has some limitations. Firstly, the data is extracted only from the Scopus database and focuses only on publications written in English, and the exclusion of "grey literature" (e.G, white papers, reports, etc.) might limit the sample size. Future studies should extend the sample size by considering publications from other scientific databases, such as Web of Science and

ScienceDirect, as well as grey literature. Secondly, the potential barriers and drivers are not directly extracted from relevant studies in the context of CBBMs. Therefore, these factors need to be tested in empirical studies to investigate whether they are relevant to the context of CBBMs and how they affect the decision to conduct the sustainability assessment of CBBMs.

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This paper and related research have been conducted during and with the support of the Italian interuniversity PhD course in Sustainable Development and Climate change. The preliminary results from this study were used to develop a questionnaire survey to collect building professionals in Flanders, Belgium, and Vietnam to test the impacts of barriers to and drivers for the sustainability assessment of CBBMs. However, this is the first study to report comprehensive results from the literature review.

Appendix

Table A1. Thesaurus file.

Label	**Replace by**
academia	
aec	architecture, engineering, and construction
architecture, engineering, and construction (aec)	architecture, engineering, and construction
barriers to use	barriers
bim	building information modeling (bim)
building	buildings
building information modeling	building information modeling (bim)
building information modelling	building information modeling (bim)
building project process	building projects
carbon emission	carbon emission assessment
carbon reduction	carbon emission assessment
construction	construction industry
economic indicators for buildings	building economics
economics	building economics
energy modeling	energy analysis
environmental impact assessment (eia)	environmental impact assessment

Label	Replace by
green construction projects	green building
inhibiting factors	barriers
integration of lca-bim	bim-lca integration
lca	life cycle assessment
lcc	life cycle costing
lcc applications	life cycle costing
lcca barriers	barriers
lcca implementation in construction	life cycle costing
lcsa	life cycle sustainability assessment
life cycle	life cycle thinking
life cycle approach	life cycle thinking
life cycle assessment (lca)	life cycle assessment
life cycle assessment and architecture	life cycle assessment
life cycle assessment for buildings	life cycle assessment
life cycle cost	life cycle costing
life cycle cost analysis (lcca)	life cycle costing
life cycle costing (lcc)	life cycle costing
life-cycle assessment	life cycle assessment
life-cycle costing	life cycle costing
practitioner survey	survey
slca	social life cycle assessment
sustainable buildings	sustainable construction practices
sustainable construction	sustainable construction practices
sustainable practices	sustainable construction practices
whole building life cycle assessment	life cycle assessment

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Exploring Circular Economy Awareness in the Cosmetic Sector: Evidence from Italian Firms.

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Abstract

The cosmetic industry is one important sector in the global economy and is increasingly involved in the search of sustainable practices aimed to mitigate its economic, environmental and social impacts, also including Circular Economy (CE) solutions. As highlighted in a previous literature review carried out by the authors, cosmetic sector's experience in practices that could be classified as circular is rooted in time and academia showed an increasing interest in the field. However, there is a lack of specific characterization of the practical implementation of CE in the cosmetic industry. To fill this gap, the present study collected evidence through survey from a sample of Italian cosmetic companies regarding their experience of CE. The survey was distributed to 367 companies from different parts of the cosmetic supply chain. A total of 47 answers were collected and qualitative analysis was carried out using the NVivo software. Results showed that CE and sustainability as perceived as interconnected. Most of respondents reported a partial or ongoing implementation level of CE practices, mainly related to the area of packaging. Less than a third of the sample assess CE, mainly using Life Cycle Assessment (LCA) method, while less than half communicate it, mainly using labels.

Introduction

Circular Economy (CE) represents a model that can guide the design of potential sustainable solutions in many business and manufacturing activities (Geissdoerfer *et al.*, 2017). The cosmetic industry represents an important and fast-growing sector worldwide (Statista, 2022). Thus, it is involved in many challenges for mitigating the economic, environmental and social impacts related to the entire life cycle of cosmetic products (Bom *et al.*, 2019). In this context, cosmetic industry is looking for sustainable solutions, also in compliance with the CE paradigm (Rocca *et al.*, 2022).

In a previous literature review carried out by the authors of this paper (Mondello *et al.*, 2024), an increasing interest of academia in this field is highlighted. Scientific articles exhibit how CE could provide sustainable solutions, for example for the formulation of cosmetic products (Novara *et al.*, 2022), or for their packaging (Civancik-Uslu *et al.*, 2019).

In this context, it is important to consider the commitment of the European Commission (EC), which published many regulations aimed to push the entire society towards sustainability and CE (EC, 2015; EC, 2019; EC, 2020). After the publication of the EU Action Plan for the Circular Economy (EC, 2015), the concept of CE starts to be widespread and become of interest of both scholars and companies. In addition, EC sets regulations aimed to the restriction of chemical substances (EC, 2006; EC, 2020), which find application in many cosmetic products. Consequently, CE could provide solutions that guarantee compliance with the EC requirements, for example for finding sustainable alternatives to synthetic materials used as ingredients or for packaging (Rocca *et al.*, 2022).

Overall, CE could support cosmetic companies also in the achievement of the Sustainable Development Goals (SDGs) settled in the United Nations Agenda 2030 (UN, 2015). One of the most relevant SDG for cosmetic industry is the No. 12, i.e. "Responsible Consumption and Production" (Cubas *et al.*, 2022), which include many important targets (e.g. 12.1, 12.2, 12.5, 12.6) achievable through CE implementation.

In this context, cosmetic companies start to develop circular solutions, despite many issues related to their practical implementation still arise (Rocca *et al.*, 2022). To the best of the authors knowledge there is a lack of empirical evidence in this field and an important gap to be filled is the missing of a specific characterization of how to implement CE in the cosmetic industry. Thus, this study aims to investigate the level of awareness and implementation of CE through the analysis of cosmetic companies' experiences of CE. In details, this study aims to collect evidence from Italian cosmetic firms, due to Italy emerges as the most active country in the research in this field (Mondello *et al.*, 2024).

Pursuing the aim of filling the highlighted research gaps, this study aims to investigate and provide evidence on i) awareness of CE, sustainability, and their link; ii) implementation of CE; iii) assessment and communication of CE.

Literature Review

Scientific literature on CE in the cosmetic industry increased after the publication of the Circular Economy Package (EC, 2015). However, the experience of cosmetic companies in circular practices seems to have begun before that date. Scientific articles published much earlier than 2015 show practices which could be considered as circular, despite the concept of CE is not even mentioned (Losso *et al.*, 2007). In addition, a connection between CE and sustainability emerges in literature (Kristensen and Mosgaard, 2020). Thus, it is important to consider the perception that companies have of these two concepts.

In addition, despite many scientific articles discuss the implementation of CE in the cosmetic industry (Mondello *et al.*, 2024), a specific characterization of that is still missing. Many scientific articles in this field discuss the potential application of CE (Del Rio Osorio *et al.*, 2021; Parisi *et al.*, 2023), but those which actually exhibit how cosmetic companies are implementing are very few.

In this context, there is a lack of empirical evidence. Thus, it is fundamental to investigate the perception of companies on both CE and sustainability, and the implementation of circular practices in the cosmetic sector.

A fundamental part of the implementation of CE is its assessment. A multitude of approaches and methods to be applied at company level are reported in literature (Roos Lindgreen *et al.*, 2020). However, some issues related to the distinction of sustainability and circularity assessment arise and empirical evidence is still missing in this field (Roos Lindgreen *et al.*, 2022).

In addition, the information provided by a CE assessment could be then communicated by companies (Laurenti *et al.*, 2018). Thus, it is important to analyze also the CE communication. Literature in this field is mainly focused on the analysis of business-to-business (B2B) communication channels, such as sustainability and Corporate Social Responsibility (CSR) reports (Morea *et al.*, 2021). On the other side,

business-to-consumers (B2C) communication tools are poorly investigated, despite a demonstrated interest to consumers' perspective (Jóźwik-Pruska *et al.*, 2022). Consequently, communication of CE in the cosmetic industry needs further investigation.

Methodology

In this study, a survey is carried out to a sample of Italian cosmetic firms. A purposive sampling technique is used to identify a population which satisfy defined criteria (Hibberts *et al.*, 2021).

More in details, companies from different parts of the cosmetic supply chain are searched, which also have a demonstrated commitment to sustainability or circularity. In addition, a focus on some parts of the cosmetic supply chain is established following the classification of Bom *et al.* (2019), which define the life cycle phases of cosmetic products (i.e. sourcing, manufacturing, packaging, distribution, consumer use and post-consumer use, and disposal). Specifically, a focus on the companies involved in the sourcing, manufacturing, and packaging phases is established, in order to capture information where the managerial choices of companies regarding CE are taken (Bom *et al.*, 2019).

The target population which meets the established criteria is defined using the member list of "Cosmetica Italia" Association, which includes more than 600 companies from cosmetic supply chain involved in sustainability-related initiatives (Cosmetica Italia, n.a.). The full member list is extracted from the Association's website, which provides full contact information of 522 firms. All of these are then classified using the ATECO classification (ISTAT, 2021) and then grouped according to the classification of Bom *et al.* (2019). Thus, the final population includes a total of 367 firms, which are categorized according to the sourcing (n=75), manufacturing (n=256), and packaging (n=36) life cycle phases.

The survey is developed and submitted online using the Microsoft (MS) Forms tool. A total of 5 email are sent individually to each company in the period between October 2023 and February 2024. The survey includes both closed-ended and open-ended questions and it is structured in four sections, among which the last two are dedicated to cosmetic manufacturers companies, as follows: i) general information; ii) perception of CE and sustainability; iii) implementation of CE; iv) assessment and communication of CE. The first section is aimed to collect general information about respondents, including the supply chain stage, the size, and the localization. The second section is addressed to collect information on the perception that respondents have of CE and sustainability, firstly separately and then analyzing their link. The third section and fourth sections are specifically dedicated to cosmetic manufacturers companies, due to sourcing and packaging companies are not involved into the related managerial choices of implementing, assessing, and communicating CE.

More in details, the third section has the aim of collecting information on the level of implementation of CE and the related implemented areas or reasons for a non-implementation. Three level of implementation are considered, which are full, partial, and ongoing. It has to be noted that at least one circular practice has to be designed, implemented and fully completed, for considering a full level of implementation. For partial implementation is intended that at least one circular practice is designed and partially implemented, while for ongoing implementation, at least one circular practice is at least designed.

The fourth section is aimed to understand if cosmetic companies assess and communicate CE. If yes, this section is addressed to collect also information on the employed assessment methods and communication channels.

After the survey is closed, all the responses are exported first to MS Excel and then to the NVivo software (QSR International, 2024) by which a qualitative content analysis is performed (Krippendorff, 1989). This approach is appropriate for analyzing data and characterizing the experience of respondents within a specific context (Fisher, 2006).

Results and Discussion

General Information

A total of 47 respondents answer to the survey. Figure 1 reports the sample characterization defined through the first section of the survey.

The composition of the sample reflects that of the target population to which the survey is submitted. In fact, as can be seen in Figure 1.a, most of respondents are cosmetic manufacturers companies (n=39), followed by raw materials suppliers (n=5) and packaging companies (n=3).

Regarding the companies' size (Figure 1.b), respondents are classified according to the Eurostat enterprise size classes (EC, 2003) as follows: micro (1-9 employees), small (10-49 employees), medium (50-249 employees), large (>250 employees). A large part of the sample is made up of small companies (n=19), followed by medium (n=14), large (n=7) and micro (n=7) ones.

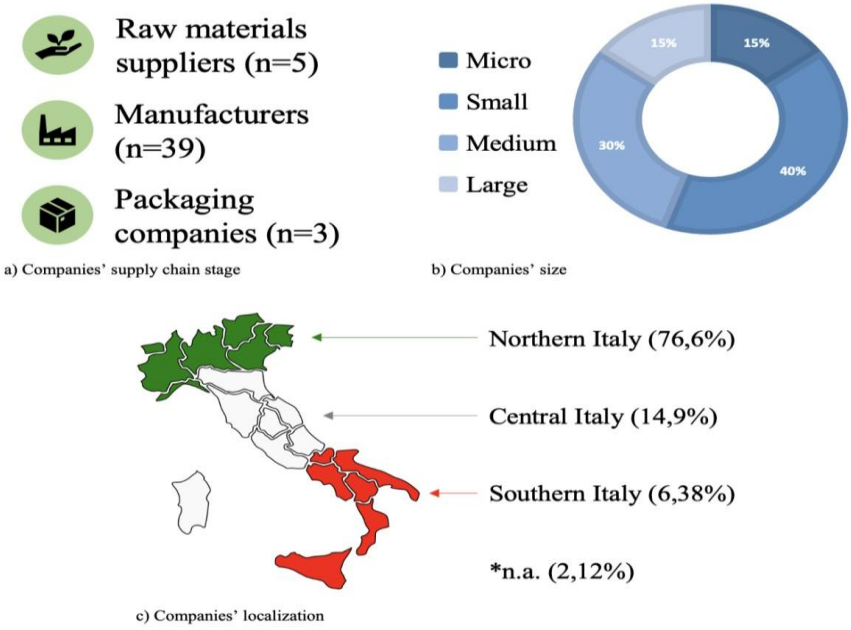


Figure 1. Sample characterization

The significant presence of small companies is easily attributable to the characterization of cosmetic sector, which in Europe included 5800 SMEs in Europe in 2022 (Cosmetics Europe, 2019) among which 776 Italian ones (Statista, 2023). In addition, in some countries SMEs represent about 80% of cosmetic manufacturers (Cosmetics Europe, 2019).

As can be seen in Figure 1.c, almost all the companies (n=36) are located in Northern Italy, while only a few in Central (n=7) and Southern Italy (n=3). Only for one respondent data on company's location is not available.

Perception of Circular Economy and Sustainability

For analyzing the perception of respondents, two-word search queries are carried out using NVivo. The aim is to identify the most employed terms for describing CE and sustainability, also for understanding the relation between the two concepts. Results are reported in two-word clouds (Figure 2).

First of all, it is interesting to note that respondents use the term "sustainability" for describing CE much more than the term "circular" for describing sustainability, which is employed only once. When describing sustainability, all the three dimensions are mentioned, i.e., environmental, social, and economic, with reference to the balance between all of them or only between environmental and social ones. On the contrary, when describing CE, only references to the environmental dimension emerge. In addition, references on the 3Rs framework are made, i.e., reduce, reuse and recycle. Finally, it is interesting to note the recurrent use of the term "waste" and "lifecycle".

Overall, these results confirm a link between CE and sustainability, especially regarding the environmental dimension, which is already reported in literature (e.g., Cosmetics Europe, 2019; Mondello *et al.*, 2024). In this regard, cosmetic industry is facing many environmental concerns (Cosmetics Europe, 2019), consequently CE is perceived as a potential solution for mitigating the environmental impacts of the entire life cycle of its products (Mondello *et al.*, 2024).

In addition, as reported in literature (e.g. Bassi and Dias, 2019), the 3Rs framework assumes importance in the investigation of CE. The attention to reduce, reuse, and recycle, is thus confirmed also specifically regarding the cosmetic sector. However, it has to be noted that considering the 4Rs framework, which includes the recovery principle in addition the three above-mentioned, despite this principle emerges as very important in scientific research on CE in the cosmetic industry (Mondello *et al.*, 2024), it is not mentioned in the respondents' answers. This may depend on the awareness of respondents on 4Rs paradigm.

Finally, the occurrence of "waste" and "lifecycle" terms could be easily explained by previous literature on CE (Rocca *et al.*, 2022; Kristensen and Mosgaard, 2020; Bom *et al.*, 2019). Indeed, many studies report waste optimization strategies in compliance with CE (e.g. Kristensen and Mosgaard, 2020), as well as the connection of CE model with the Life Cycle Thinking (LCT) approach (Rocca *et al.*, 2022; Bom *et al.*, 2019).

a) Perception of Circular Economy b) Perception of Sustainability

Figure 2. Perception of a) Circular Economy and b) Sustainability

Implementation of Circular Economy

Figure 3 reports the results related to the analysis of cosmetic manufacturers' responses (n=39). It is interesting to note that less than one third of respondents (n=12) reports a full implementation of CE, while the number is more than double for partial (n=27) and ongoing (n=26) levels of implementation. This result could be due to the composition of the sample, mainly characterized by small companies, which could not have yet the necessary economic resources to invest in the CE implementation as reported in literature (e.g. Rocca *et al.*, 2022; Roos Lindgreen *et al.*, 2022).

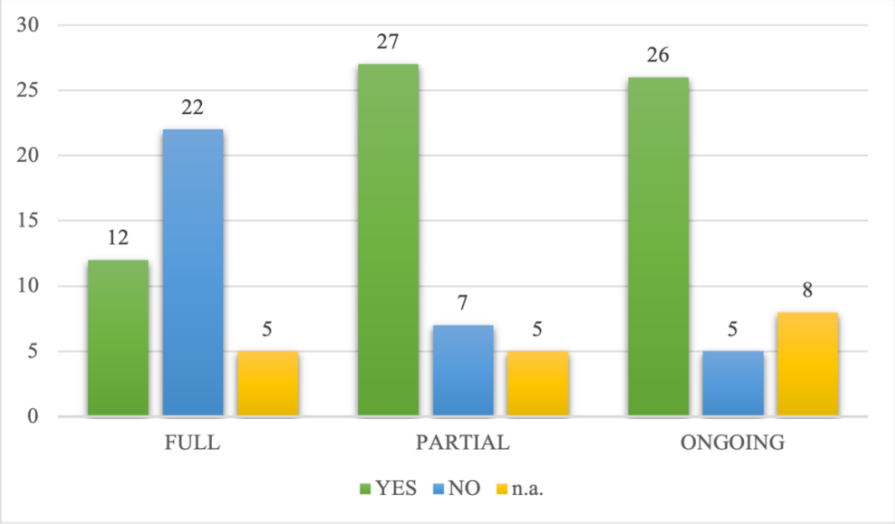


Figure 3. Levels of implementation of Circular Economy

The areas in which CE is implemented is analyzed through NVivo by using a word frequency query for identifying the most employed terms in describing the areas of each level of implementation. Results are reported in a word cloud (Figure 4).

It is evident the importance given to the packaging area, regardless of the level of implementation, which is mentioned by 22 out the 39 respondents. In addition, respondents give much importance to the use of recycled and recyclable materials, both in formulations and packaging, and to the reduction of waste.

It is interesting to note that cosmetic companies are very involved in the implementation of CE in the packaging area, reporting many circular practices implemented. For example, the use of recycled and recyclable materials for packaging, the elimination or reduction of plastic materials, the creation of refill models, or the reduction of overpackaging, are mentioned by respondents.

Noteworthy is also the mention of the term “agri-food”, linked to the circular practice of using agrifood waste as ingredients for cosmetic formulations. However, despite the importance of the agri-food sector emerges in literature in this field (Del Rio Osorio *et al.*, 2021; Parisi *et al.*, 2023; Mondello *et al.*, 2024), only two respondents mention it in their answers.

Figure 4. Areas of implementation of Circular Economy

The reasons for which companies do not fully, partially, or ongoing implement CE are also analyzed and reported in Figure 5.

Many respondents, whose companies do not have a full implementation of CE, report that circular practices are still in a design phase. However, for companies which do not even have a partial or ongoing implementation of CE, the main reported reasons regard the time and costs required, the lack of information or training, or that CE is out of the company’s strategy or not requested by their consumers. Overall, respondents’ answers confirm that the main reason why companies have not yet implemented CE may be the companies’ size, as already highlighted for the levels of implementation.

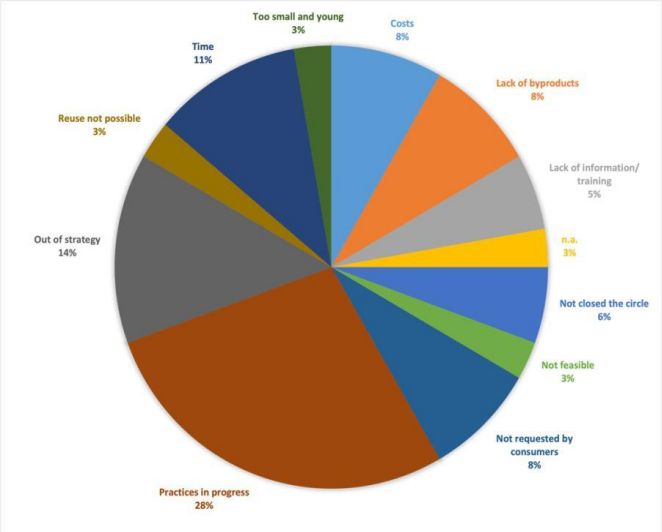


Figure 5. Reasons for non-implementation of Circular Economy

Assessment and Communication of Circular Economy

From the analysis of cosmetic manufacturers' responses (n=39), emerges that only less than one third of respondents (n=14) assess CE and about half of them (n=20) communicate their CE commitment or practices. In details, the relation between companies which do or do not assess and communicate CE is analyzed and reported in Figure 6.a. The chart shows the majority of companies which assess CE also communicate it, as well as majority of companies which do not.

In addition, the assessment and communication of CE is analyzed considering the companies' size (Figure 6.b). It is interesting to highlight that as the companies' size increases, also the percentage of companies which assess and communicate CE increases. This result is also consistent with what emerges on the levels of implementation.

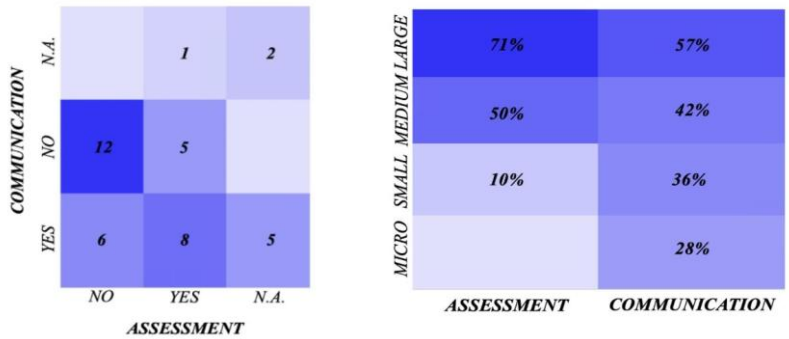


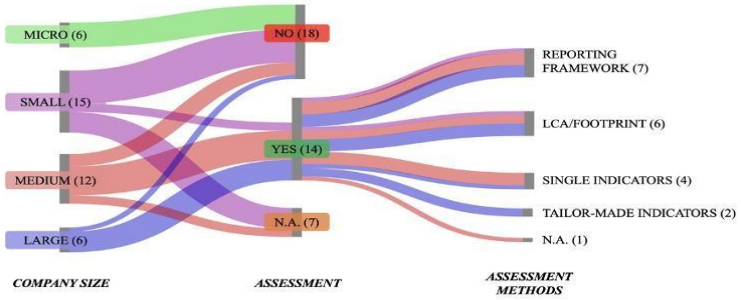
Figure 6. Assessment and communication of Circular Economy

Similar results are already showed in literature (Rocca *et al.*, 2022; Roos Lindgreen *et al.*, 2022).

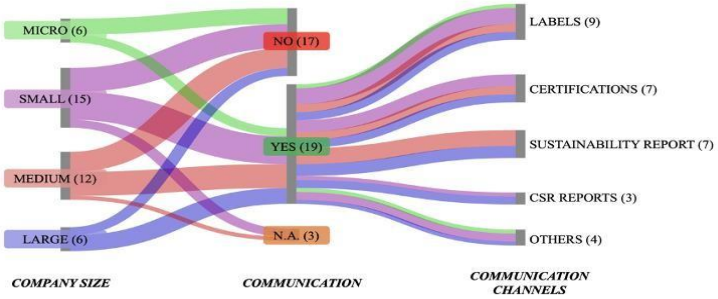
For example, Roos Lindgreen *et al.* (2022) pointed out how larger companies have less awareness on CE and, consequently, they assess CE more frequently than smaller ones. In addition, Rocca *et al.* (2022) discuss that smaller companies have less resources to invest in CE implementation, thus if companies do not implement CE they also do not assess or communicate it.

The assessment methods and communication channels employed by companies are also analyzed (Figure 7), considering the companies' size. In particular, it has to be noted that each respondent could report more than one employed method and/or channel. Regarding the assessment of CE (Figure 7.a), the only two small companies which assess CE report the use of reporting framework or LCA/footprint, while single indicators are mainly employed by medium companies, and tailor-made indicators are employed by only large companies. Overall, the most employed methods are reporting framework and LCA/footprint.

The importance of the LCT approach and the use of LCA/footprint methods also emerge in literature on CE (Rocca *et al.*, 2022; Roos Lindgreen *et al.*, 2022). In addition, LCA and other LCT approaches (e.g., Environmental-, Carbon-, and Water-Footprint) are often employed in the cosmetic industry with the aim of developing products with improved environmental profiles (Cosmetics Europe, 2019). Thus, this result is also consistent with the predominant attention of respondents to environmental dimension. Regarding the communication of CE (Figure 7.b), micro companies declare using only labels or other channels such as social media, while small companies report using different channels except for sustainability reports, which are employed only by medium and large companies. Overall, the most used communication channels are labels, followed by certifications and sustainability report.



a) Relations among companies' size, assessment of Circular Economy, and assessment methods



b) Relations among companies' size, communication of Circular Economy, and communication channels

Figure 7. Relations among companies' size and a) assessment and related methods, and b) communication and related channels

Literature on CE in the cosmetic industry deeply investigate the use of sustainability and CSR reports for communicating the circular practices of companies (Fortunati *et al.*, 2020; Morea *et al.*, 2021; Tiscini *et al.*, 2022). However, these studies mainly take into consideration cosmetic multinational companies (Fortunati *et al.*, 2020; Morea *et al.*, 2021), or exhibit that the only references to CE in sustainability reports regard environmental topics (Tiscini *et al.*, 2022) or are largely lightweight (Opferkuch *et al.*, 2022). The results of the present study highlight that CSR reports are not often employed, and sustainability reports are used only by medium and large companies. Thus, research in this field should be planned to consider specific information to communicate and other communication channels, which could be used by companies regardless of its size.

In summary, LCA/footprint emerge as the most used assessment methods among the surveyed companies, while labels and certifications are the most employed communication channels. Despite it is out of the scope of this study to deep dive into the specific assessment methods and communication channels used by companies as well as their connection, it is interesting to highlight that the connection between evaluation and communication of CE can be confirmed but need to be further investigated.

Conclusion

This study is aimed to provide empirical evidence on CE implementation in the cosmetic industry. Considering the findings of a previous literature review carried out by the authors of this paper (Mondello *et al.*, 2024), Italy is chosen as reference country for this study and a focus on some life cycle phases of cosmetic supply chain (i.e. sourcing, manufacturing, and packaging) is established.

A survey is administered to a population of Italian cosmetic firms, which is identified using a purposive sampling technique. The final sample is composed by cosmetic manufacturers (n=39), raw materials suppliers (n=5), and packaging companies (n=3).

The survey structure includes four sections. The first section is aimed to collect general information about respondents and results show that most of respondents are small companies, but also a significant presence of medium, large, and micro-ones emerges. Almost all of them are located in Northern Italy.
The second section is addressed to collect information on the perception of CE and sustainability of respondents. A positive relation between CE and sustainability emerges, especially considering the environmental dimension. However, from the respondents' answers CE is often connected to sustainability, while sustainability is not necessarily connected to CE. In addition, the perception of sustainability includes aspects related to both environmental, social and economic dimensions, while that of CE includes only aspects related to the environmental one.

The third section is dedicated to cosmetic manufacturers for collecting information on the level of implementation of CE, also considering the areas of implementation or the reasons for nonimplementation. In particular, three levels of implementation of CE are considered: full, partial, and ongoing. Only less than one third of respondents reports that have already fully implemented CE, while more than double reports a partial or ongoing implementation of CE. Regarding the areas of implementation, the most attentive is that one of packaging. Regarding the reasons behind a

nonimplementation, most respondents report that circular practices are still in a development phase, while other reasons that emerge are the costs and time required, the lack of information or training, and that CE is out of the company's strategy

The fourth section, which is again dedicated to cosmetic manufacturers, aims to collect information on the assessment and communication of CE, also considering the employed methods and channels, allows to grasp a relation between assessment and communication of CE. In addition, as the companies' size increased, the percentage of companies which assess and communicate CE increased as well. Finally, reporting framework and LCA/footprint emerge as the most employed assessment methods, while labels, certifications, and sustainability reports as the most employed communication channels.

Overall, this study provides a first step in bridging the gap in the empirical evidence on CE in the cosmetic industry. The main findings bring light on the Italian cosmetic firms' perception of CE and sustainability, implementation of CE, assessment and communication of CE. In addition, insights on where further research should be planned in this field are highlighted.

However, some limitations of this study also emerge. For example, the composition of the sample may have influenced the obtained results, due to only Italian cosmetic firms from specific part of the cosmetic supply chain are considered. In addition, the assessment and communication of CE require deeper analysis as the specific methods and channels used are not included in the questionnaire.

Overall, scientific and managerial implications arise. First of all, empirical research in this field needs to be expanded, for example considering the implementation of CE for cosmetic packaging, or specific assessment methods and communication channels. In addition, from companies' responses it is clear that CE is often argued mainly considering environmental aspects. Thus, more attention to economic and social issues should be given. Finally, companies should invest more in employee training on CE, due to a lack of information emerge from answers on reasons for non-implementation.

Acknowledgement

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Submission ID: 43

How Aquaculture Addresses Environmental Challenges through Circular Economy Adoption: Evidence from the Italian Sector.

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Abstract

Aquaculture is a growing industry in Europe, where people consume a lot of fish but have limited wild fish stocks. To meet the demand, Europe relies on both local aquaculture and imports from other countries. Local aquaculture involves raising aquatic species in controlled or semi-controlled environments, both in seawater and freshwater. The EU's aquaculture output has risen by 11% since 1990 but has fallen by 8% since 2018 (FAO, 2022). In 2020, European aquaculture supplied about 21% of the domestic demand for fish and shellfish. Italy is a leading producer of aquaculture food, both marine and freshwater, as the third European producer with around 120 thousand tons. Italian aquaculture is known for the quality and variety of its products, however, some environmental challenges affect it, such as: a) fish feed impacts connected to the use of wild fish as feed; b) pollution from fecal matter and unused feed; c) escapes of farmed fish that may interbreed with wild populations; d) loss of materials due to production by-products that often remain completely unused and destined for landfill, rather than being reintroduced for producing valuable compounds (such as protein, omega-3, chitin). In this context, the circular economy (CE) model may offer opportunities and challenges for aquafarmers. On one hand, it can help to reduce the environmental impact of aquaculture, improve the efficiency and quality of the products, and make the sector more self-reliant and resilient. On the other hand, it can require significant changes in the management of resources, production, and market, which can entail costs, risks, and barriers. Aquaculture entrepreneurs must therefore be ready, innovative, and flexible to seize the benefits and face the challenges of the CE. This paper builds on a previous comprehensive literature review that examined the CE in the aquaculture and found that Italy is one of the leading countries in the world for circular options in aquaculture. Therefore, in the present study Italian aquaculture farmers' attitudes and practices are examined by highlighting: a) the CE awareness and interest; b) the CE practices for environmental sustainability; c) the barriers to the CE transition; d) the opportunities emerging from the CE model. Data are collected through an online survey distributed to a sample of 220 farms that belong to the main Italian trade association, (Associazione Piscicoltori Italiani) producing more than 90% of the Italian aquaculture supply. The results show how farm types, company size, species bred, and CE awareness affect the adoption of CE practices. Therefore, some common challenges among the farms emerged, such as regulatory fragmentation, new production patterns and lack of training on environmental issues. Future research activities will add a validation phase with the key-informant entrepreneurs through dedicated interviews. Therefore, the findings highlight CE criteria as drivers. In addition, the scrutinised practices may stimulate entrepreneurs to analyse their hot-spots and move towards circular practices based on the 4Rs for valorising waste and by-products. Furthermore, this will achieve the protection of underwater life, according to SDG 14 (indicators 14.1 and 14.2), as well as Goals 12 and 8.

Introduction

Aquaculture, farming aquatic organisms in controlled environments, is one of the fastest growing agrifood sectors worldwide (FAO, 2022). This growth is essential for food security and to meet the growing demand

for fish products, particularly due to the decline of capture fisheries. In Europe, aquaculture is crucial to meet high fish consumption rates of around 25 kg per capita per year (EUMOFA, 2023). With the depletion of wild fish stocks, the OECD and FAO predict that European aquaculture will soon exceed the supply of wild fish (OECD/FAO, 2022). However, the sustainability of the aquaculture sector is under scrutiny due to its environmental impact/effects and resource dependence (Ahmad *et al.,* 2022). In detail, aquaculture has both positive and negative environmental impacts. On the positive side, it can be more efficient than traditional agriculture regarding water and land use (Sacramento *et al.,* 2022). It can also provide a more sustainable source of seafood, particularly for regions with limited access to wild fish (FAO, 2018).

Nevertheless, several environmental issues are associated with aquaculture (FAO, 2010; Napolitano *et al.,* 2022; Oosting *et al.,* 2022). Key concerns include the release of nutrients into ecosystems (Ottinger, Clauss and Kuenzer, 2016), dependence on fishmeal from over-exploited stocks and land availability (Natale *et al.,* 2013; Kok *et al.,* 2020; Ciriminna *et al.,* 2021). To address these issues, new strategies and technologies have emerged, focusing on sustainable practices such as integrated multi-trophic aquaculture (IMTA), recirculating aquaculture systems (RAS) and climate-smart aquaculture (Klinger and Naylor, 2012; Boffa *et al.,* 2022). As aquaculture plays a strategic role in providing food for a growing population, the European Commission has defined strategic guidelines for a more sustainable and competitive European aquaculture (European Commission, 2021b). These guidelines align with the European Green Deal (European Commission, 2020b) and the Farm to Fork strategy (European Commission, 2020a). In light of the European Commission's recommendations, researchers have been growing interested in proposing practices that, in a holistic approach, can help move the aquaculture production process towards a circular economy (CE).

In this context, Italy is one of the leading aquaculture producers in Europe, and it has attracted the attention of researchers due to its sustainability challenges and CE practices (Cozzolino *et al.,* 2023). Despite being a major producer of mussels, freshwater fish and caviar (STEFC, 2023), little is still known about Italy's efforts to implement CE practices. This paper aims to investigate how Italian aquaculture entrepreneurs are adopting CE principles to achieve sustainable production practices, bridging the gap between academic research and practical implementation on farms. The study focuses on several key aspects: awareness of CE principles among aquaculture entrepreneurs, current environmental sustainability practices, barriers hindering the transition to CE, and emerging opportunities in the sector. An online survey methodology was used to conduct this research, distributed to members of the Associazione Piscicoltori Italiani (API), representing 38% of Italian aquaculture farms (STEFC, 2023). The survey included aquaculture producers from different regions of Italy who were involved in both freshwater and marine farming. It aims to provide a comprehensive insight into the adoption of CE practices within the Italian aquaculture industry. By involving a significant number of producers, the study provides a detailed perspective on the industry's readiness and challenges in adopting CE principles. The preliminary findings serve several purposes: i) firstly, understanding the perspectives of Italian aquaculture producers regarding the theoretical adoption of circular practices; ii) secondly, evaluating the current status of the CE transition at the farm level based on farmers' knowledge of CE principles; and iii) thirdly, identifying perceived barriers and opportunities for this transition.

Literature Review

The CE is increasingly seen as crucial for reducing environmental impacts by promoting resource efficiency and recovery, which lowers waste and emissions compared to traditional linear systems. Chary *et al.*

(2022) argue that CE can significantly cut the environmental impacts of human activities through better resource use and recovery. Muscat *et al.* (2021) introduce five ecological principles for steering biomass use towards CE. While CE has shown benefits for marine resource conservation and added value in aquaculture (Sanz-Lazaro and Sanchez-Jerez, 2020; Casado-Coy *et al.,* 2022), the sector was not initially included in Europe's strategic actions for CE, as seen in the first Circular Economy

Action Plan (European Commission, 2015). The European Green Deal (European Commission, 2019) recognises aquaculture's potential for climate neutrality and environmental sustainability. The specific strategy for aquaculture (European Commission, 2021a, 2021b) further acknowledged CE as a key opportunity for making the European aquaculture sector more competitive and resilient. Starting with the Green Deal (2019) and followed by the European Commission's 2021 Communication, the initially weak and fragmented regulatory framework in aquaculture hindered the adoption of a holistic and environmentally friendly approach (Smith *et al.,* 2010; Ahmad, W. Hassan and Banat, 2022) and has attracted the interest of academics. Thus, researchers have focused on the potential opportunities to improve the environmental sustainability of aquaculture (Kundu *et al.,* 2022). While these principles' benefits are well-documented in land-based food systems, their application in aquaculture remains underexplored. According to the findings of a previous review conducted by the authors of this paper (Cozzolino *et al.,* 2023), current literature on CE in aquaculture mainly focuses on experimental and research-driven practices and CE strategies for aquaculture include: a) reducing environmental impacts by using fewer natural resources (Regueiro *et al.,* 2021) by exploring alternative ingredients for sustainable aquaculture (Pereira *et al.,* 2022; Piazzon *et al.,* 2022; Pleić *et al.,* 2022; Zarantoniello *et al.,* 2022); b) reusing process water, such as for algae production (Pereira *et al.,* 2022), and improving water quality with low-nutrient-release feeds (Albrektsen *et al.,* 2022); c) recycling of waste to create new products or energy sources (Monteiro *et al.,* 2018) and by-products for the production of new valuable compounds (Laso *et al.,* 2018; Coppola *et al.,* 2021; Zhan, Lu and Wang, 2022). Furthermore, other authors have focused on economic methodologies for CE practices (Gatto and Re, 2021) and on possible interactions between different economic sectors, such as construction, through the valorisation of fish by-products, recycling of shellfish waste (Vélez-Henao, Weinland and Reintjes, 2021; Summa *et al.,* 2022; Elegbede *et al.,* 2023), and chemical-pharmaceutical, experimenting with the extraction of bioactive compounds from fish by-products (Coppola *et al.,* 2021; Rebouças *et al.,* 2023). Furthermore, a need for socio-economic studies to integrate CE effectively into business models (Jacob *et al.,* 2021) also emerged. Although the cited literature review (Cozzolino *et al.,* 2023) shows that about 39% of circular practices investigated by academia have been tested in the Italian area, it remains uncertain if these practices have been tested at the company level and, therefore, their implementation in businesses is not confirmed and not well-documented. This gap hinders a deep understanding of CE's real-world impact and the sector's transition to sustainability. Collaborative efforts and stakeholder involvement, as emphasised by Cooney *et al.* (2021; 2023), are crucial for bridging this gap and assessing the economic feasibility of CE practices from farmers' perspectives. Empirical data on CE practices' adoption and effectiveness at the business level are lacking, impeding progress towards a sustainable, competitive, and resilient aquaculture sector.

Methodology

The research employed a questionnaire-based survey methodology (Figure 1): highlighting the effectiveness of traditional data collection techniques for investigating contemporary issues like the CE in aquaculture.

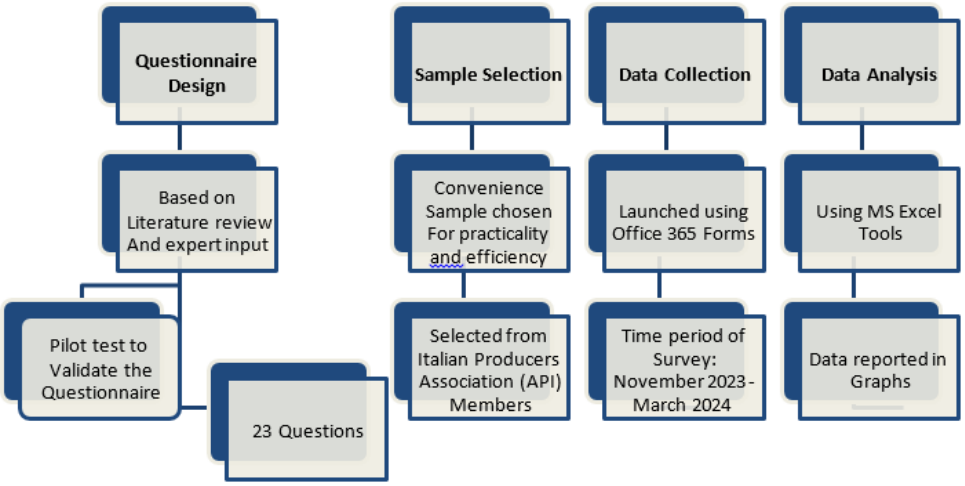

Figure 1. Research methodology steps for the convenience sample survey

While questionnaires are commonly used to explore market trends from the consumer perspective, their application to engage producers and raise awareness of environmental sustainability issues has been less frequent (Siva *et al.,* 2019). A convenience sample method was chosen (Stratton, 2021) to involve many producers without restricting respondent characteristics (Taherdoost H, 2018), ensuring that participants represented active aquaculture enterprises. This was facilitated by involving the Associazione Piscicoltori Italiani (API), which includes 220 members who produce over 80% of Italy's total fish supply and represent about 38% of the Italian universe of aquafarms (MASAF, 2021; STEFC, 2023). The study harnessed valuable practical insights by engaging this sample, bridging the gap between theoretical concepts and real-world practices. The questionnaire, designed with expert input and informed by key literature on global circular practices (Mutalipassi *et al.,* 2021; Albrektsen *et al.,* 2022; Zhan, Lu and Wang, 2022; Cooney *et al.,* 2023), was a critical tool for assessing the sector's transition towards sustainability.

The data collection process began with a thorough pilot phase, during which the questionnaire was tested by academic experts, key stakeholders, and experienced producers. This step was crucial to ensure the clarity and relevance of the questionnaire before its full distribution. Office 365 Forms was selected as the data collection tool due to its user-friendly interface and accessibility. The survey was launched in November 2023 and closed in March 2024; reminders were sent every two weeks to encourage participation. The questionnaire was also introduced at the annual API members' meeting in February 2024, significantly boosting interest and participation. All participants provided informed consent before starting the questionnaire, adhering to ethical standards and ensuring the integrity of the research. The data collection resulted in 104 responses. Finally, the collected data underwent a detailed analysis to understand the level of awareness of CE and identify barriers to its adoption in aquaculture. Data analysis was performed using MS-Excel, with the main results summarised in graphs and tables. The questionnaire was divided into three homogeneous subject areas where the questions were grouped following the purpose of the data collection: (1) structural information, (2) data on transitions towards sustainability, and (3) specific challenges and opportunities related to CE based on farmers' direct experiences. This comprehensive approach provided a nuanced understanding of the multifaceted nature of aquaculture practices. In particular:

- the first section collected information to profile the sample of respondents by geographical area, farm size (by number of employees and volume of seafood farmed annually), technology and aquatic farming environment (marine or freshwater) and species farmed;
- then, in the second section, related to the transition towards sustainability, respondents were asked to report actions they have implemented, are considering, or find not applicable/not applied based on practices frequently mentioned in recent literature. This section avoided direct references to the CE or its synonyms to ensure unbiased responses;
- finally, in the third section, questions aimed to gauge awareness of CE principles by asking about familiarity with CE and soliciting critical responses to statements describing CE. Additionally, respondents were asked to reflect on and rate potential limitations and opportunities related to CE using a Likert scale to record their judgement of the proposed options to answer (Jebb, Ng and Tay, 2021).

Results and Discussion

The systematic organisation of the questionnaire results provides a comprehensive view of the aquaculture industry's move towards sustainability. The "Sample overview and description" section provides important baseline data that is essential for contextualising the rest of the findings. The "Moving aquaculture towards sustainability" section is particularly revealing, showing how far the industry has adopted sustainable practices and the current benchmarks. Finally, "Challenges and opportunities of CE transition for farms" is a deep dive into the practical application of CE principles, highlighting the real challenges and opportunities facing aquaculture farmers. This structured analysis not only maps the current landscape of sustainable practices, but also points to future directions for growth and development in the sector.

Sample Overview and Description

The survey conducted among 220 API members highlights Italian farmers' commitment and interests, especially regarding sustainability and CE principles. With a response rate exceeding 47% (104 respondents), there is evident strong interest in these topics within the farming community. The dedication of respondents is also reflected in the time spent on the questionnaire, averaging 11 minutes, which is 4 minutes longer than the estimated duration. This indicates a careful consideration of the questions, demonstrating the seriousness with which respondents addressed these issues and their interest in the 23-question survey. Companies were categorised into five clusters based on the number of employees, allowing for a detailed understanding of sustainability practices across different company sizes. Most responses came from micro-sized companies (less than 9 employees), showing a significant representation of this segment (Figure 2). This aligns with the prevalence of micro-enterprises (up to 9 employees) in Italian aquaculture statistics (MASAF, 2021). Therefore, the sample's representativeness and the data collected provide a solid foundation for developing targeted strategies that cater to the specific needs and capabilities of each cluster, promoting inclusive and effective sustainable practices in the aquaculture sector.

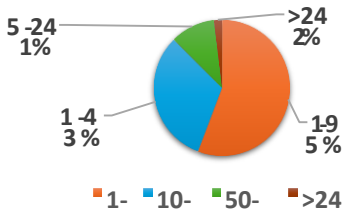

Figure 2. Sample of aquafarms (%) by number of persons employed

The survey revealed a significant concentration of responses from Northern Italy (Figure 3), with Veneto, Friuli Venezia Giulia, Lombardy, and Trentino Alto Adige accounting for over 55% of the total responses. In contrast, no responses were received from Valle d'Aosta, Basilicata, Molise, and Calabria. Two main factors can explain this result:

- Historical tradition: historically, aquaculture in Italy began in Northern Italy as a secondary activity by power plants. These plants used cooling water from turbines to experiment with freshwater species farming.
- Current development: aquaculture remains largely unexplored in some regions, particularly those that did not respond to the questionnaire.

According to MASAF (2021) census data, the four regions that did not respond (Valle d'Aosta, Basilicata, Molise, and Calabria) represent less than 2% of Italian aquaculture enterprises. Meanwhile, the regions with high survey participation host more than 47% of national aquaculture enterprises, ensuring the survey's representativeness.

Figure 3. Respondents (%) by regional farm location

The questionnaire was distributed to API-registered members, but their specific roles within the companies were not initially known. As the survey topics required detailed knowledge of the company's organisational structure, production process and supply chain, it was essential to analyse the respondents' roles and the size of their companies, categorised by number of employees. The analysis showed that more than 70% of the questionnaires were completed by people heavily involved in management, including owners (58%) and veterinarians (14%) (Figure 4).

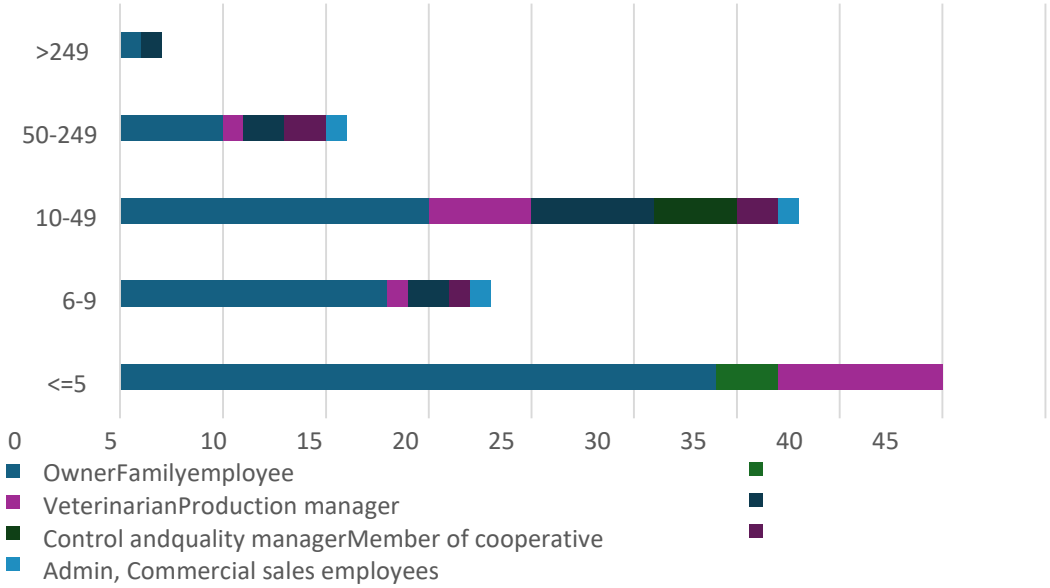

Figure 4. Role of the respondent on the farm by size of the number of employees

This is significant as it confirms that respondents are involved in strategic and organisational decisions within their companies and bring valuable experience, knowledge and expertise in managing production and mitigating aquaculture's impacts on aquatic and terrestrial ecosystems. The survey also highlighted a variability in the role of respondents within medium to large farms (50 or more employees). In contrast, smaller farms (up to 10 employees) showed a dualism between owners or legal representatives and veterinarians. Veterinarians, in particular, act as a bridge between management and innovation, providing technical and scientific support to redesign practices. They propose the use of unconventional feeds and implement sustainable management of waste, by-products and effluents. The questionnaire also collected information on extensive, semi-intensive and intensive farming methods to determine whether the sample represented all three methods as classified internationally by the FAO (FAO, 2017). Thus, the sample comprises 32% intensive farms, where all farming stages are artificially controlled. In contrast, 58% are semi-intensive, where some stages are not artificially supported. For example, in clam and mussel farming, seed is sourced from natural beds authorised by public authorities.

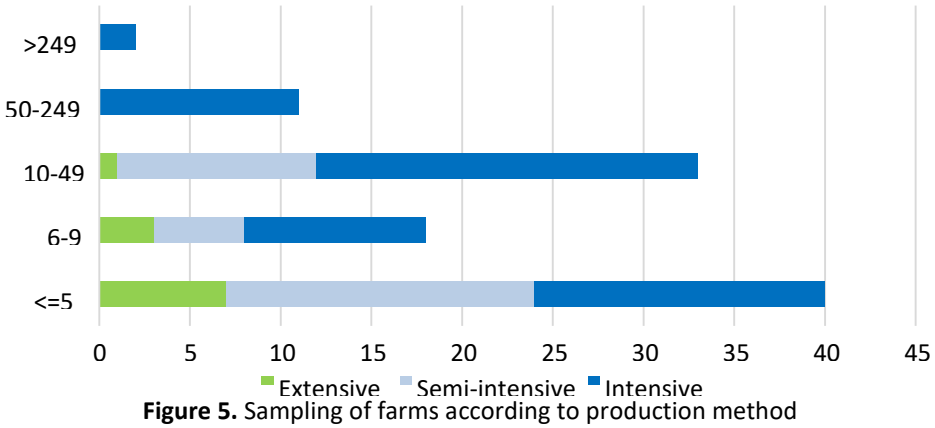

Figure 5. Sampling of farms according to production method

The remaining farms are extensive, specifically "vallicolture", where minimal human intervention focuses on maintaining ecosystem health. These coastal areas, isolated by man for fish culture, are crucial for providing ecosystem services to wetlands (Cautadella and Spagnolo, 2012). The survey findings align with national statistics on Italian production structures, validating the distribution of extensive, semi-intensive, and intensive farming methods currently used in Italy (MASAF, 2021).

Moving aquaculture towards sustainability

This section examines how farms address sustainability challenges to develop a sustainable model. The questions explored practices that enhance environmental, economic and social sustainability. Respondents were presented with nine circular practices classified according to the European waste hierarchy's 4Rs paradigm (reduce, reuse, recycle, recover), prioritising material consumption over energy. In this way, respondents indicated their commitment to specific practices and shared their views on practices they considered not applicable or not used in their process models (Figure 6).

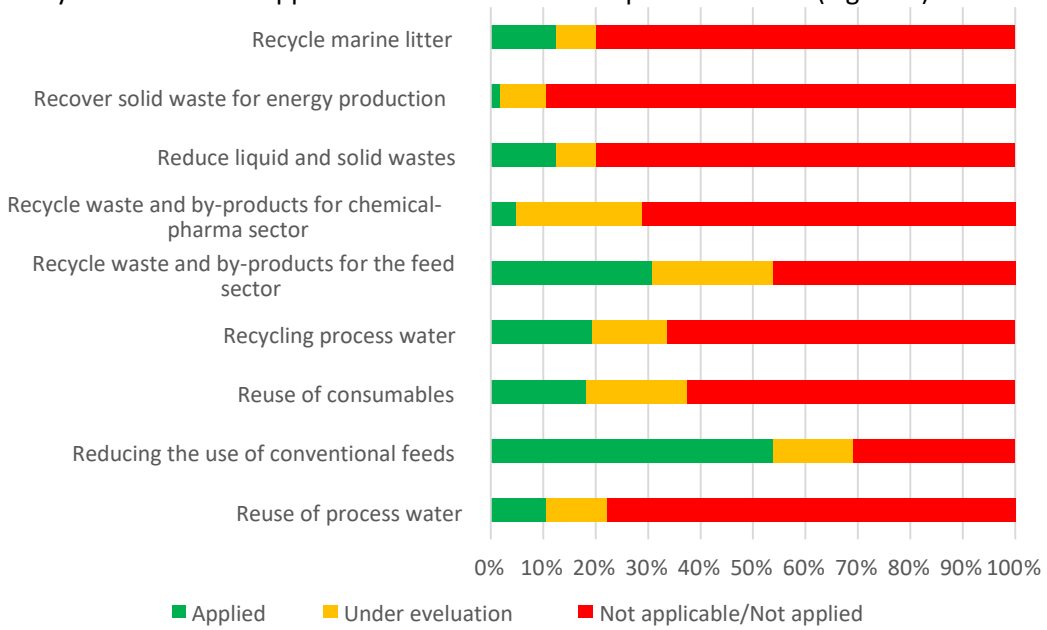

Figure 6. Proposed CE practice options in aquaculture: their status (applied, under evaluation, not applicable/not applied) within the sampled farms

In general, the "not applicable/not applied" option was selected by 30% to 90% of sample, according to the different proposed practices. This indicates that respondents may not have actual knowledge of all the practices suggested in the questionnaire and therefore have no empirical experience of their actual applicability.

Approximately 33% of respondents reported that they had already adopted more sustainable feed practices. This finding is consistent with the literature, where many studies are testing feeding practices based on more sustainable and circular animal and plant ingredients (Vishwakarma *et al.,* 2022). In particular, the commitment to redesign current feeding protocols by substituting conventional feeds is widespread across all company sizes in the sample (Figure 7). Responses indicate that the percentage of

respondents substituting conventional feeds ranges from 38% in aquafarms with fewer than 5 employees to over 70% in the 10-49 employee cluster, demonstrating broad adoption of this practice.

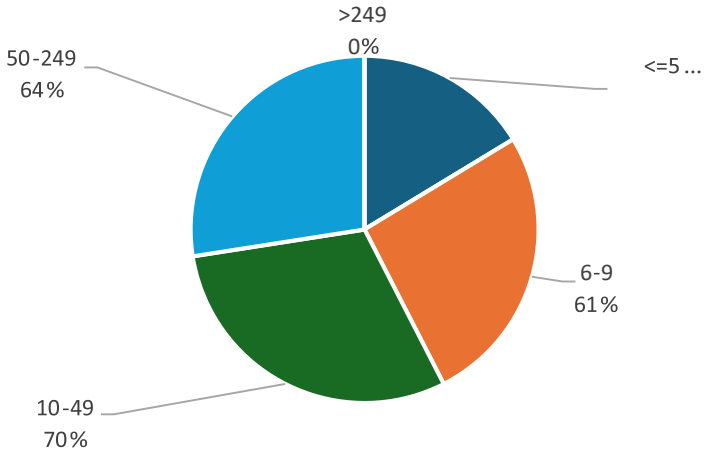

Figure 7. The percentage of companies in each employee class implementing practices to reduce the use of virgin raw materials in conventional feeds

Respondents also reported recycling the process water stream and by-products. The recycled water stream is used for agricultural irrigation as a biofertiliser, while the by-products are mainly used in the feed industry. Conversely, energy recovery is the least practiced method. This may be because many of the companies, mainly micro-enterprises with up to nine employees, do not generate sufficient quantities of organic waste to support anaerobic processes. As a result, such waste is more commonly used in agriculture as manure.

Italian farmers' awareness of the potential for their wastes and by-products to enter circular economy processes was analysed, together with their knowledge of the end uses of their processing wastes (byproducts). The most common response, especially from micro-enterprises with less than 5 employees, was "I don't know" (Table 1). This indicates a lack of understanding among these farms about the potential uses of their waste and by-product. This also may mean that there is not much interaction or dialogue with the waste collection service providers. If there were more cooperation, this could have helped farmers to gain more knowledge and interest in relation to these issues.

Table 1. Respondents' awareness (%) of their waste/by-products' use

Farm Size	I don't know	Organic fertiliser for agriculture	Ingredients for flours and oils intended for animal feed	Ingredients and molecules used in pharma-chemicals-nutraceuticals	Ingredients used in the food industry for human consumption	Biogas for energy production
<=5	43%	43%	29%	45%	0%	0%
6-9	16%	14%	18%	27%	67%	100%
10-49	35%	36%	45%	18%	33%	0%
50-249	6%	7%	8%	9%	0%	0%
>249	0%	0%	0%	0%	0%	0%

Challenges and opportunities of CE transition for farms

The survey evaluated respondents' knowledge and awareness of CE principles, focusing on the challenges, aquaculture businesses face in pursuing sustainability goals. Respondents were asked if they were aware of CE principles before completing the questionnaire. Almost all (93%) reported awareness, suggesting a significant potential for implementing cleaner production models. In the literature, Hamam *et al.* (2021) argue that producers' and stakeholders' knowledge of CE principles can promote the widespread adoption of circular production models. This also increases responsibility and awareness, highlighting the need for appropriate policies and instruments. The results of the present survey therefore confirm the importance of CE knowledge. The data aimed to identify a) the most widely recognised barriers to the application of circular practices; b) the benefits and opportunities that could be derived from circular practices. The results showed that legislative aspects and bureaucracy were consistently rated between 4 and 5 as limiting factors (Figure 8).

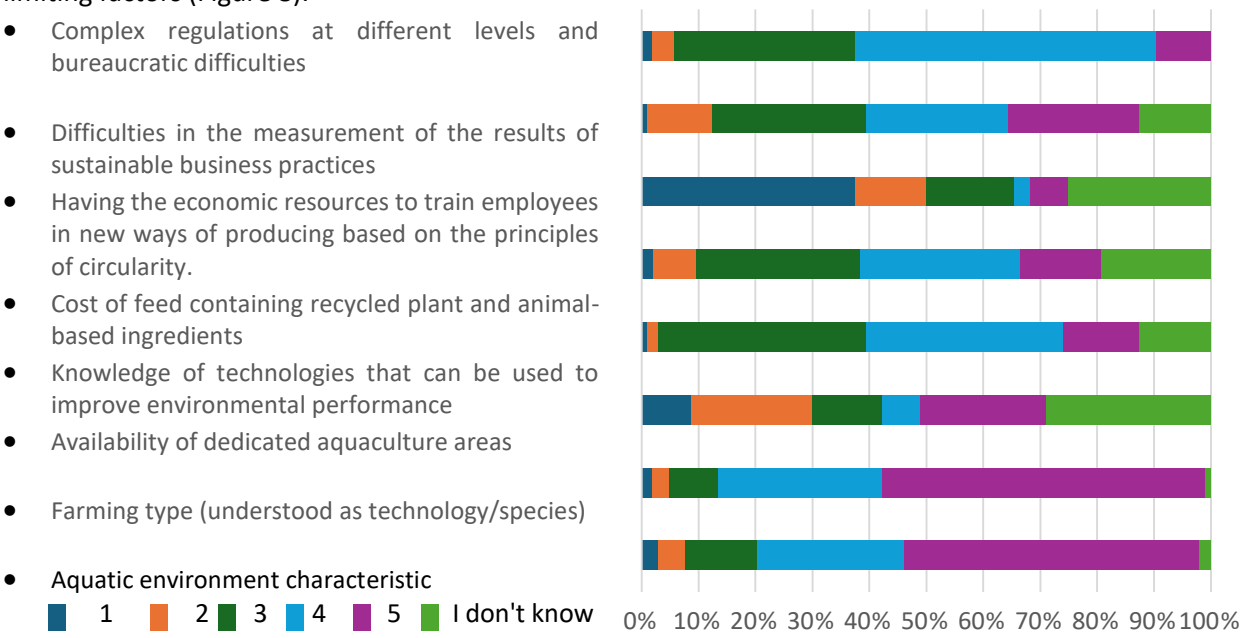

Figure 8. Distribution of perception of respondents about the constraints and barriers in adopting CE practices. (Likert-scale: 1= not limiting; 5= high limiting)

In addition, the technology used by aquaculture companies and the difficulty of measuring and monitoring the impact/effect of CE practices on the environment were notable internal constraints. Although the questionnaire included an option on the availability of resources (human and financial) to train staff in CE principles, only 10% of respondents rated this as a constraint between 4 and 5. Conversely, around 60% did not consider it to be a significant constraint. Interestingly, 25% of respondents answered, "I don't know", indicating a lack of clarity and awareness of the human resources needed and their skills to facilitate the redesign of production, management and supply models in aquaculture.

Respondents were asked to assess the opportunity that CE principles could offer if applied to their production practices. This was to see how these principles might help the whole sector reach sustainability

goals, in line with international and national strategies for sustainable aquaculture growth. Over 63% of respondents rated this opportunity as 5 (high opportunity) for achieving the sector's sustainable growth objectives. Finally, the results were analysed in terms of the identification of opportunities and benefits in relation to the different options proposed and based on the three pillars of sustainability: economic, environmental and social. The analysis shows that the main benefits generated by the CE relate to the environmental aspects, which are considered a priority by the sample, followed by the economic benefits and opportunities (Figure 9).

From an environmental perspective, circular practices aimed to reduce dependence on natural resources and raw materials were emphasised. This includes redesigning production models to reduce pressure on wild fish stocks used for fishmeal and oils. In addition, interest in feed based on recycled ingredients is also driven by the need to reduce costs, which currently account for 35-50% of fish farming costs, according to European economic statistics (STEFC, 2023).

However, the transition to non-conventional feeds faces economic hurdles, with over 60% finding them less competitive than conventional options. While the environmental benefits of CE are recognised, there's less emphasis on the social benefits. This is consistent with wider research showing that while farmers' value environmental protection and cost savings, social impacts such as community well-being and cultural values are less tangible and less prioritised in sustainability practices (Campanati *et al.,* 2022; Colombo *et al.,* 2022).

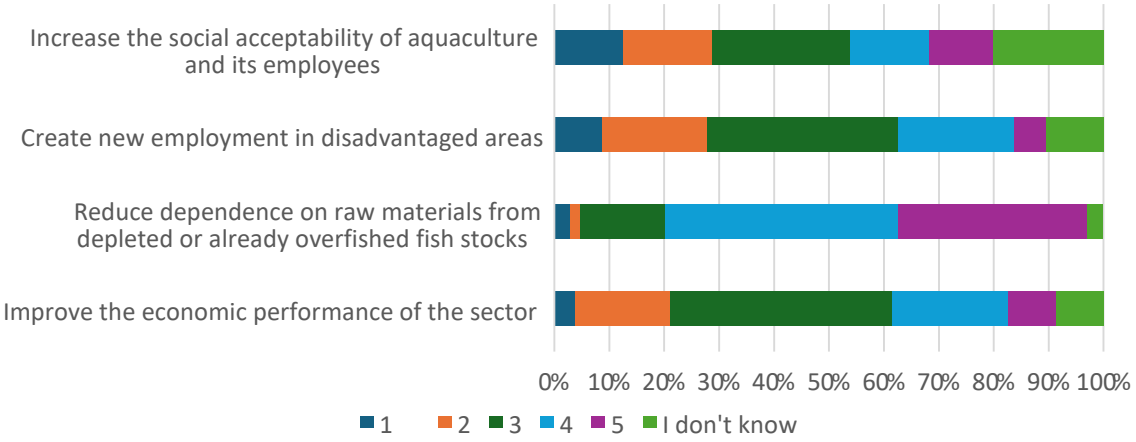

Figure 9. Distribution of respondents' perceptions about the opportunities and benefits of adopting CE practices. (Likert-scale: 1= low opportunity; 5= very high opportunity)

Adopting CE principles in aquaculture presents significant opportunities for enhancing environmental and economic sustainability. Although challenges remain, particularly in the economic competitiveness of sustainable feed options, the long-term benefits make a strong case for their implementation.

Conclusion

Based on the preliminary results of the survey, Italian aquaculture shows a strong commitment to CE principles and environmental responsibility. There is a clear awareness of CE among stakeholders, which

is crucial for promoting sustainable practices. Significant progress is evident in adopting technologies that reduce dependence on non-renewable resources, reflecting proactive sustainability efforts. Furthermore, the results underline the central role of CE principles in promoting sustainability. Italian aquaculture farmers are adopting the 4Rs (Reduce, Reuse, Recycle, and Recover) to reduce dependency on natural resources and turn waste into valuable resources. This shift is in line with several of the UN Sustainable Development Goals (SDGs):

SDG 14 aims to conserve the oceans and reduce marine pollution. Farming practices contribute by minimising waste and protecting marine ecosystems.

SDG 12: Promotes sustainable consumption and production patterns, supported by farmers' investment in sustainable feed.

SDG 8 focuses on sustainable economic growth and decent work for all, supported by adopting CE practices in aquaculture.

However, regulatory barriers remain a significant challenge, particularly for smaller businesses that lack the resources to navigate complex regulations. Tailored initiatives are recommended to support aquaculture companies in their transition to sustainability, ensuring that the three pillars of sustainability are equally addressed. The sample shows that sustainability in aquaculture is not only based on environmental and economic dimensions, but the social dimension is not yet significantly recognised among the options of circular practices and their derived benefits. The results advocate a balanced approach integrating environmental, economic and social dimensions in sustainability initiatives. Including the social dimension in decision-making processes will be essential to ensure resilience, promote environmental stewardship, enhance economic viability and address societal needs. In addition, a gap in understanding how to measure environmental impact was identified as a barrier to the full adoption of CE. Targeted education and support initiatives are needed to address this gap. Employee engagement emerges as a key driver of sustainable practices, highlighting the need for comprehensive training and support within organisations.

Current research, while insightful, is limited by its sample size and scope. To truly assess the viability and impact of CE practices, future studies should aim to include a more diverse and extensive sample, extending beyond Italy to other Mediterranean regions also known for their aquaculture activities. This expansion would not only increase the representativeness of the findings but also provide a more nuanced understanding of regional differences and similarities in CE adoption. In addition, addressing the limitations identified, such as the convenience sampling method and potential subjective biases, will be critical to strengthening the reliability and applicability of the research findings. In doing so, the resulting data could serve as a robust basis for developing comprehensive CE strategies that can be adopted by policymakers and industry leaders worldwide, ultimately leading to a more sustainable and resilient aquaculture industry. These initial findings are relevant in informing future strategies and policies to support Italian aquaculture farms in their journey towards environmental sustainability. They lay the groundwork for further research and development initiatives that can enhance the adoption of CE practices across the sector, thereby promoting sustainable production methods and effectively addressing environmental challenges.

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Circularity and Sustainability Indicators for the Agrifood Sector: The Case of Olive Oil Supply Chain

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Abstract

The urgency to optimize resource use and reduce waste generation has led the global attention to the Circular Economy (CE). Today, the agri-food sector (AFS) throws away one-third of its production, severely impacting the ecosystem and society. In this context, the olive oil supply chain is one of the most impactful for resource depletion and waste production. Thus, CE may be a valuable opportunity to redirect the sector towards sustainable development. Several studies reported examples of circularity in olive oil and AFS, but there is not a unique approach to CE assessment for this context, which relies on the so-called biological cycles. Thus, the present study performs a bibliometric analysis to map the literature on CE assessment in the food and olive oil context, tracking the evolution of the topic, identifying criticalities, and capturing possible future trends. Results show: i) increasing interest in the topic, ii) Europe as a relevant player, and iii) the centrality of Life cycle assessment as an impact assessment metric. The study is part of the Research Projects of National Interest (PRIN) 2022 "Towards circular and sustainable agri-food systems: metrics for assessment (CIRCULAGRIS)" CUP J53D23009360006 – code 2022JNNJJX, supported by Ministero dell'Università e della Ricerca (MUR).

Introduction

In the last decades, the food production model allowed it to meet the growing food demand from an expanding population (Santagata *et al.*, 2021). However, the global population will reach 10 billion by 2050, resulting in economic, social, and environmental impacts on food production and consumption (Silvestri *et al.*, 2022). In this context, Circular Economy (CE) is perceived as a model to reconcile society's needs for healthy and quality food while preserving the ecosystem (Ghisellini *et al.*, 2023). In a circular agri-food context, natural resource preservation is central, optimizing resource use and improving nutrient recirculation. Moreover, CE encourages shortening the supply chain by promoting local food systems; this supports local realities, increases the well-being of the community and reduces transportation environmental issues (Rodino *et al.*, 2023). Among the agri-food supply chains, relevant is the potential of olive oil production for the transition to sustainable development (Kounani *et al.*, 2023). Indeed, olive oil production is associated with land degradation and air emissions; however, it offers valuable circular valorisation options for its by-products (Ncube *et al.*, 2022). For this reason, metrics able to monitor CE and consider the specificities of the olive oil supply chain are urgently needed (Kounani *et al.*, 2023). The agri-food Sector (AFS) has a nutritional and cultural role in our society with relevant impacts on economic, environmental, and social dimensions of sustainability (Silvestri *et al.*, 2022). Nevertheless, circular does not mean sustainable (Rigamonti and Mancini, 2021), thus measuring the circular strategies implemented by the companies of the sector is a crucial step to assessing their real contribution to sustainable development. Assessing circularity allows companies to collect solid data to guide their strategic decisions, but also to improve companies' image by preventing greenwashing (Coluccia *et al.*, 2023). However, there is not a unique approach to measure circularity. On the one hand, there are metrics

for assessing the impacts related to CE strategies implementations (e.G, Life Cycle Assessment - LCA, or Material Flow Analysis - MFA), on the other, metrics targeted to assess the level of circularity of a given strategy or process (e.G, Material Circularity Indicator - MCI). However, despite the LCA allows the assessment of the potential environmental impacts linked to CE practices, it does not measure their level of circularity (Roos Lindgreen *et al.*, 2021). On the contrary, circularity indicators are only focused on circularity-specific goals (e.g., resource efficiency), missing the link between circularity and sustainability (Samani, 2023).

The study aims to identify CE metrics that are suitable for the agri-food context, regarding the olive oil sector. To do so, this exploratory study aims to identify the main themes present in the sample of articles analysed and to define inclusion and exclusion criteria consistent with the scope of the project, which will subsequently be the subject of a systematic analysis. Therefore, the present research adopts a bibliometric analysis of the studies available in peer-reviewed literature on the topic. This allows to highlight emerging trends to guide future research avenues.

This study is part of the project "Towards Circular and Sustainable Agri-food Systems: Metrics for Assessment" (CIRCULAGRIS), which promotes the design of circular and sustainable metrics for three crucial food supply chain in the Italian context: wine, olive oil, and pasta and wheat supply chains. The project aims to support decision-makers in developing strategies in line with sustainable development goals by collecting tools able to assess the actual sustainability of circular practices applied to the AFS.

Literature Review

CE assessment in the AFS Hitherto, circularity indicators have usually been used to assess technical systems, namely inert materials. On the contrary, the AFS relies on the so-called biological systems, made of organic materials that dissolve after use (Møller *et al.*, 2023). Moreover, the AFS is complex since it covers all the steps from the production to the consumption of agri-based products, thus involving several stakeholders with different interests (Banerjee *et al.*, 2024). This context makes CE assessment particularly challenging in the agri-food system. Probably for this reason, several authors addressed the topic in the last years, starting from Velasco Muñoz *et al.*, 2021, who mapped CE implementation and assessment in the agricultural supply chain. Then, Poponi *et al.* (2022) created a dashboard of 102 indicators for the entire AFS. The authors proposed a systematization of such indicators according to the areas of sustainability and the scope of measurement covered. Other reviews followed, collecting indicator and assessment methodologies for addressing agri-food-based circularity (Silvestri *et al.*, 2022; Rodino *et al.*, 2023; Fassio and Chirilli, 2023). Recently, one review focused on the CE assessment of the olive oil supply chain (Kounani *et al.*, 2023), highlighting the great potential in valorising by-products from olive oil production, e.G, using them as feedstock for other productive processes. Some studies measured the sustainability and circularity of impacts associated with CE practices in the olive oil supply chain (Ncube *et al.*, 2022; Espadas-Aldana *et al.*, 2023). However, few studies measured the actual circularity of it, while most of the indicators selected are adapted to this specific supply chain (Kounani *et al.*, 2023). In general, the issue is not the lack of assessment metrics but their high fragmentation. Some indicators collected serve the same purpose, making the information collected redundant (Poponi *et al.*, 2022). This makes it very difficult for companies in the sector to choose appropriate assessment metrics, leaving room for greenwashing phenomena. The recent release of the ISO series 59000 provides a guide for companies to

implement and assess circularity (ISO, 2023). Nevertheless, it is not sector-specific, which makes more research and interest in addressing the features of the AFS as a whole and the specific supply chains while assessing CE needed.

Methodology

A bibliometric analysis of the existing scientific literature is conducted to address the research question. Bibliometric analysis allows researchers to analyse a large volume of contributions available on a given database (Banerjee *et al.*, 2024). Specifically, bibliometric analysis enables tracking the evolution of scientific knowledge on a specific topic, capturing its nuances with a structured approach (Donthu *et al.*, 2021). Furthermore, to ensure the robustness and replicability of the research procedure, the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) method is adopted as the formal guideline of this study (Page *et al.*, 2020).

Data Collection

Figure 1 shows the overall search strategy, i.e., the keywords chosen, and the inclusion and exclusion criteria adopted in the screening process to identify the final sample. To identify studies reporting CE assessment metrics in the AFS in general and the olive oil supply chain in particular, the following keywords are selected: "indicator*" OR "measuring" OR "monitoring" OR "metric*" OR "assessment" AND "agri-food" OR "agrifood" OR "agro-food" OR "olive oil" OR "olive*". The search is made through Web of Science (WoS) database, and it is updated to May 2024. Allowing the first identification of 175 studies addressing the search query. The initial sample is then reduced by adopting the following database search filters: i) peer-reviewed articles and reviews, ii) articles in English, and iii) at the final stage of publication. The final sample has 168 publications.

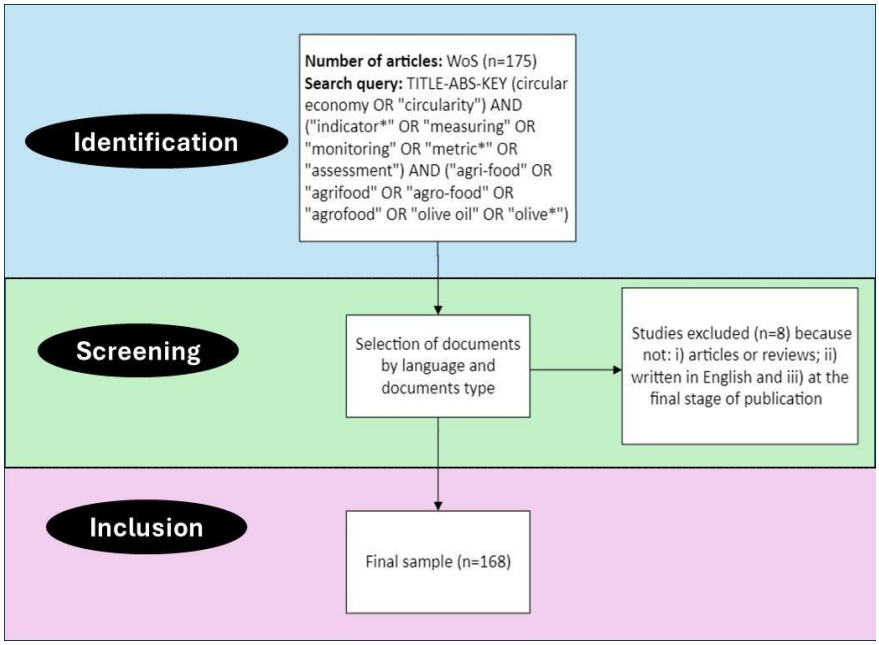

Figure 1. Search strategy overview

Results and Discussion

Yearly Distribution and Growth Trend

The real interest in measuring circularity in agribusiness began in 2016 with only one publication and then underwent a huge increase in following years. In absolute terms, 2022 presents the highest number of publications (n=48), with a slight decrease in 2023 (n=42), while 2024 still presents a low number as it is still in progress. The interest in circularity in the sector and its measurement dates after 2015, the year of publication of the Action Plan for the CE, which already included the reduction of food loss and waste among its main objectives (European Commission, 2015).

Despite a slight decline in 2023, the relevance of the topic has been increasing over the years, thanks also to the numerous non-interventions that have recognised the central role of the AFS in the path towards sustainable development and the numerous interventions in favour of circularity, especially in the European context through the Green Deal and specifically the Farm to Fork initiative, entirely focused on the resilience and sustainability of the food supply chain (European Commission, 2020).

Most Influential Sources

The top 10 journals evaluated based on the number of publications in the research area under study are shown in Figure 2. The highest number of publications is attributed to Sustainability (n=24), Journal of Cleaner Production (n=21) and Resources, Conservation and Recycling (n=8). Sustainability is a journal with an international scope, covering various aspects of sustainability such as its technical, environmental, cultural, economic, and social dimensions. Journal of Cleaner Production also aims to address sustainability with a specific focus on Cleaner Production, which aims to prevent waste production, while proposing an efficient use of resources and social capital. Resources, Conservation and Recycling have a vocation for resource management practices in their technological, environmental, economic, and institutional dimensions with specific attention to recycling and resource substitution. Other journals focus on a more specific dimension of sustainability, such as the International Journal of Life Cycle Assessment (n=6), which focuses precisely on LCA applications.

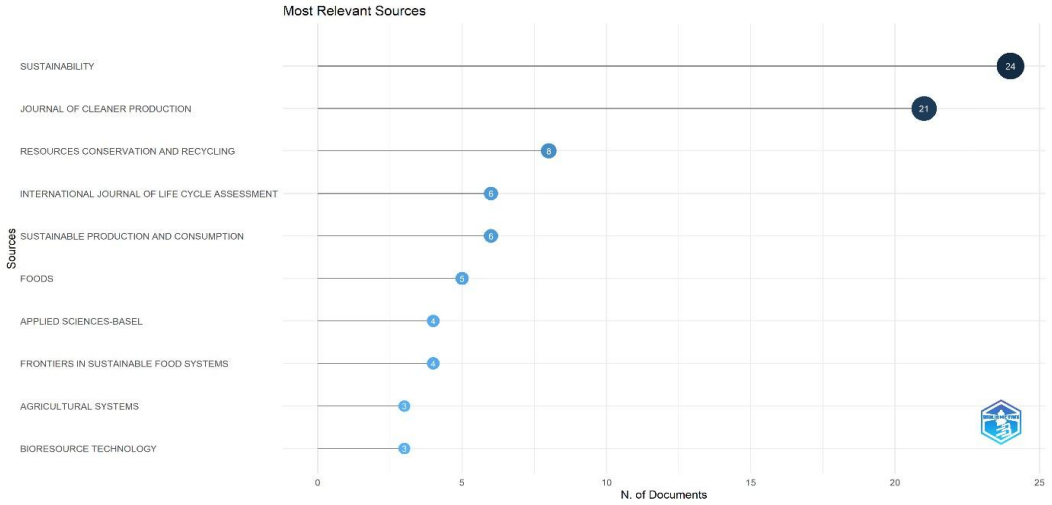

Figure 2. First ten leading journals in terms of publications.

This suggests that circularity metrics are not only the subject of interest of journals focusing on specific methods of analysis, such as the International Journal of Life Cycle Assessment, or focused specifically on the sector, such as Foods; rather, but the greatest number of publications are also in journals interested in sustainability in a broader sense, a symptom of the centrality of the topic within the debate on circularity and sustainability *tout court*.

Most Relevant Countries

Figure 3 represents the countries having the highest number of publications. The analysis covers all the 168 articles of the sample. The centrality of European countries in general and Mediterranean countries in particular is evident from the map. Italy presents the highest number of studies (n=155), followed by Spain (n=63), France (n=23), Greece (n=23) and Portugal (n=22). This abundance of studies on the subject in the European context is undoubtedly due to its leading role in the transition towards sustainable development. One example is the farm-to-fork initiatives, which include ensuring sustainable food production among its pillars. Moreover, the new Common Agricultural Policy (CAP) (2023-2027) shares with the Green Deal several sustainability objectives such as preserving natural resources and biodiversity, in continuity with the Green Deal (Ghisellini *et al.*, 2023). Concerning Italy, the latest Circular Economy Report reports a comparative assessment of the circularity performance of European countries based on a series of indicators developed by the European Commission, confirming Italy's leading role compared to countries such as Germany and France (Circular Economy Network, 2024). Italy's interest in the measurement of CE is also evidenced by UNI/TC 11820, which aims to measure circularity at the organisational level but without focusing on a specific sector (UNI, 2022).

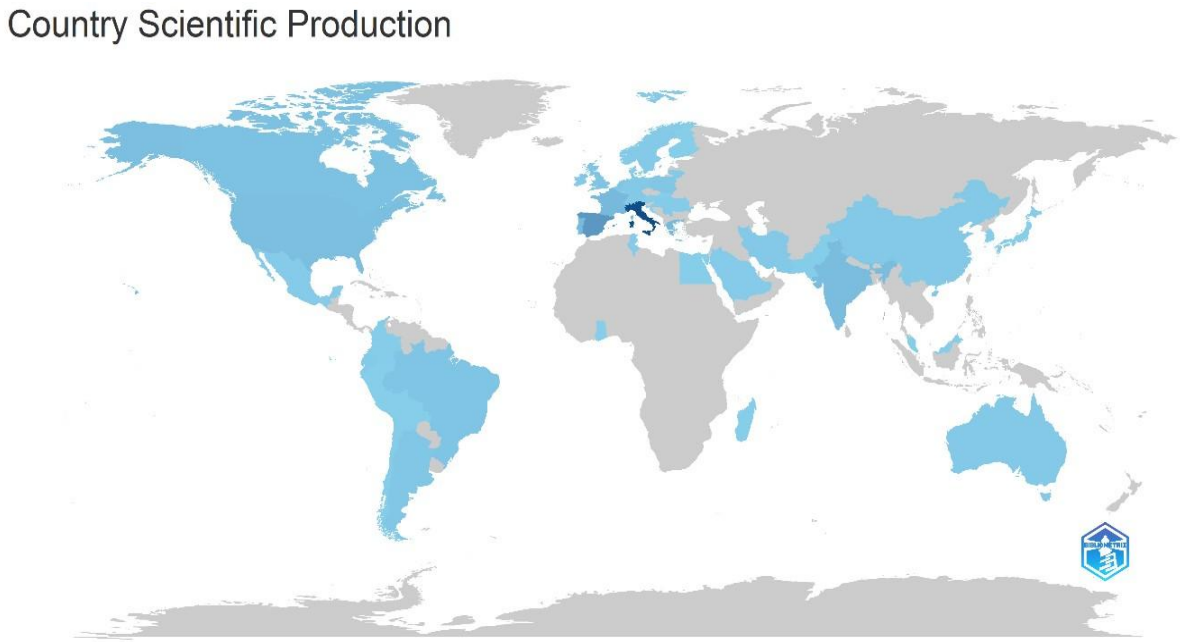

Figure 3. Most relevant countries in terms of publication on the topic

Keywords Analysis

First, the co-occurrence of the authors' keywords trending between 2004 and 2024 was assessed using network visualisation. To do this, the VOS viewer software (van Eck and Waltman, 2010) was used using specific selection criteria, i.e. it set a threshold of 3 minimum occurrences of a keyword; thus, out of 655 keywords, only 41 met the criteria (results are reported in Figure 4). The most frequent keyword is "Circular economy", which has the highest occurrence (101) and the strongest linkage (147), followed by "Sustainability" and "Life Cycle Assessment". The most relevant metric for the CE measurement at the level of keywords is "Life Cycle Assessment", followed by the generic “Indicators” and with much less weight by "Material flow analysis". Other relevant high linkages of keywords are "Biorefinery", "Food waste" and "Bioeconomy", suggesting the high interest in using agro-food waste as input for processes such as biorefining. Also, interesting, is the presence among the top 10 keywords of "Olive pomace", a waste from olive oil production and the subject of various valorisation practices (EspadasAldana *et al.*, 2023; López-García *et al.*, 2021).

The analysis then identified 5 clusters represented in different colours, i.e., Red, Green, Blue, Yellow, and Violet. The Red cluster includes terms such as "agri-food", "food loss and waste’", “agri-food byproducts” and “recycling”. The focus on food waste and loss is highly connected to the CE, being a base principle of circularity, which redefines the concept of waste to give it a connotation as a resource (De Bernardi *et al.*, 2023). The Green cluster is focused on “bioeconomy” but also mentions two assessment metrics: LCA and MFA, while agri-food items are “food waste” and “olive oil”. The Blue cluster represents CE and sustainability as key topics mentioning as metrics LCA and the general “indicators”. The Yellow cluster shows again LCA as an assessment metric associated with “environmental sustainability” and “climate change” as a climate category. Finally, the Violet cluster includes terms such as CE, “agriculture” and “olive pomace” as items. The LCA is present several times in the sample as it is present both in extended form, with or without the hyphen, and as an acronym. In any case, LCA does not directly measure the circularity of processes or products but rather the environmental impact associated with CE strategies implementation (Samani, 2023), which is crucial given the lack of alignment of circularity and sustainability. However, for a full assessment of circularity, it is also necessary to analyse the level of circularity of the strategies implemented by firms through specific indicators (Rigamonti and Mancini, 2021).

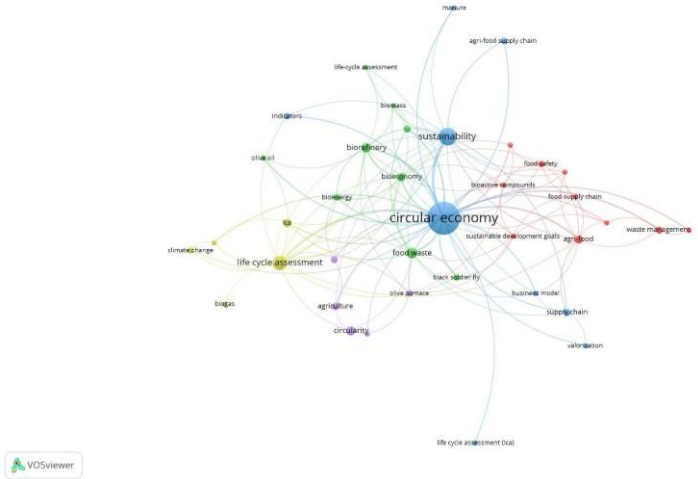

Figure 4. Visualisation of the author's co-occurrence network of keywords (2004-2024)

Next, the analysis of the Keywords Plus was collected by WoS using the Biblioshiny R application (Le *et al.*, 2023). Keywords Plus represents all those terms present and repeated in the titles of the content's citations but not in the title of the article analysed. As shown in Figure 5, the size of the circles is correlated with the search frequency of the keywords plus: The bigger circles are associated with a frequency between 40 and 50, medium ones around 30 and small ones between 10 and 20 times. The most prominent trend topics are in 2022. Specifically, "life cycle assessment" shows the highest frequency (n=50), followed by "management" (n=38) and "waste" (n=24). Concerning 2021, the great interest is in "circular economy" (n=14), followed by a more generic "impact" (n=12) and “food waste” (n=9). This demonstrates the great interest in the life cycle approach for measuring circularity, especially through waste management and valorisation strategies.

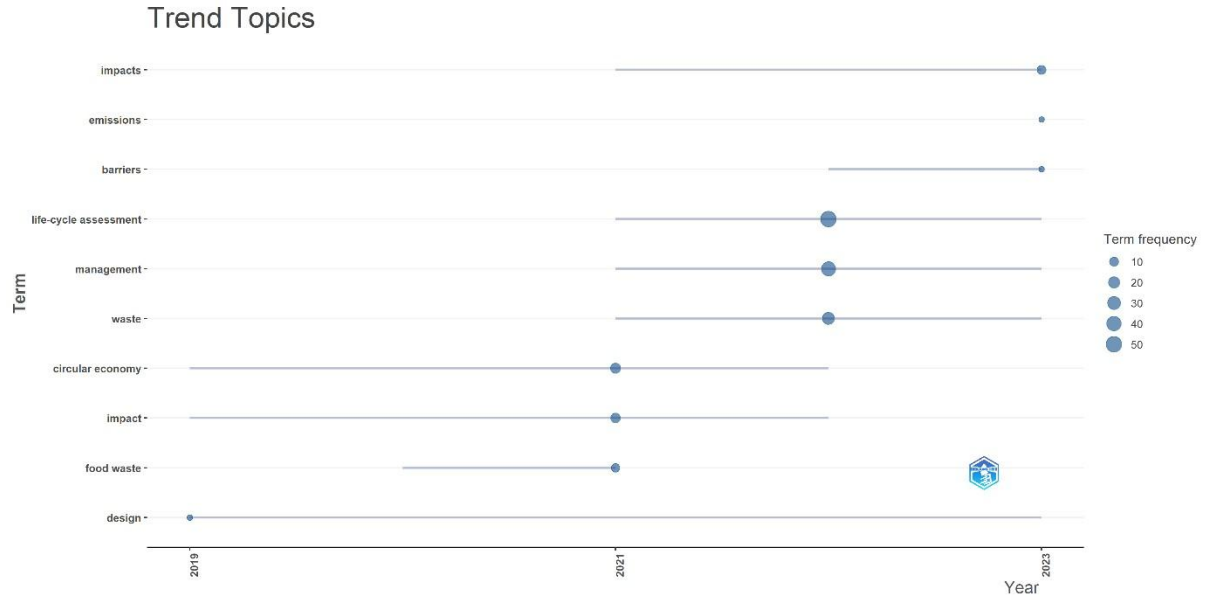

Figure 5. Trend topics analysis (Keywords Plus)

Thematic Analysis

Figure 6 analyses the abstracts of the articles in the sample, showing the development degree (Density) against the relevance degree (Centrality). Specifically, the graph, drawn with the aid of the Bibliometric R Package, considers constructs with two words (i.e., bigrams) out of a total of 250 words considered with a minimum Cluster Frequency of 5. Among the motor trends, i.e., those topics of great interest for the development of the area analysed, relevance and a high degree of development are associated with the LCA for measuring the environmental impacts of the strategies implemented. Within this cluster, olive oil production and olive pomace are frequently associated with LCA analysis. An interesting example of a combined approach with LCA and circularity indicators in the olive oil supply chain is presented by Falcone *et al.* (2022), who applied LCA and Environmental Life Cycle Costing (E-LCC), together with the Material Circularity Indicator to assess the environmental and economic impact of the proposed strategies, as well as their level of circularity. Fair development, but limited relevance is reserved for sustainable development goals (SDGs) as objectives imposed by the United Nations and targets to achieve, with particular emphasis on waste stream reduction. Contained instead is the development and centrality of

the use of organic matter, e.g., from olive oil processing as an input for circular processes, such as anaerobic digestion, which allows the production of electricity and abnormal energy, as well as organic fertiliser as a source of nutrients for the agricultural phase (Bentivoglio *et al.*, 2022). In between basics and motor trends, there is a cluster including circular economy and agri-foodrelated terms, which are the main keywords of the upstream research process on the database and thus have great prominence within the graph. Another, but smaller, cluster between basics and motor trends identifies CE indicators and agri-food supply chain-related terms as highly relevant while limitedly developed. This is in line with the premise of the present analysis, given that CE assessment is crucial for CE adoption but is still limited in the sector (Coluccia *et al.*, 2023). Interestingly, the presence of economic and social pillars among the cluster evidences the increasing attention to other than the environmental dimension of sustainability. As niche themes, i.e. studies developed but still with limited relevance, a small cluster identifies assessment metrics for olive groves and biomass use for energy purposes. Among emerging or declining themes, high relevance but low level of development present metrics that can measure nutrient circularity. The weight of nutrients in agriculture is a determinant of environmental impacts. Chemical fertilisers are a source of soil degradation and water abiotic depletion, so a balanced supply of nutrients, e.g., recycled through composting, would reduce the associated impacts. Hence, the importance of monitoring the nutrient loop is a unique opportunity to close the resource loop by turning waste into input for the agricultural process. The remaining two clusters have a limited size: one focuses on agri-food by-products, entailing their valorisation in terms of fatty acids and additives as emerging topics that need more attention; the other focuses on by-products and safety. This aspect, declining according to the analysis, is relevant. The AFS, dealing with food, has specific regulations to ensure food safety that can limit CE implementation. For instance, in the olive oil supply chain, bureaucratic issues challenge olive oil by-product valorisation (Ncube *et al.*, 2022).

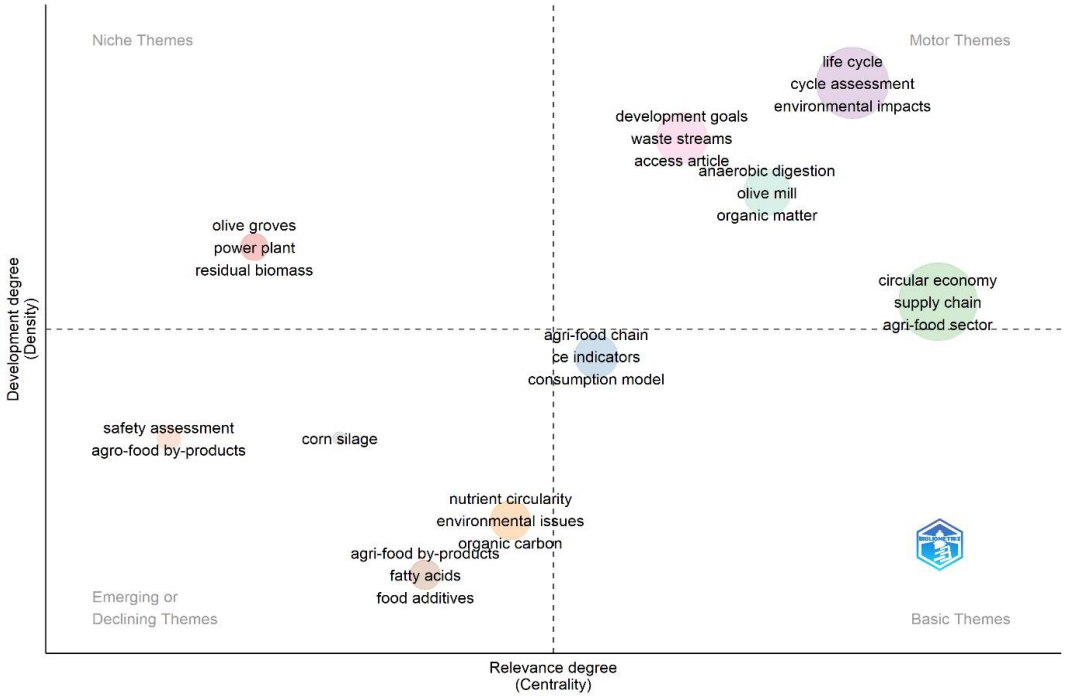

Figure 6. Thematic analysis of the article's abstract

Criteria Selection

The thematic analysis carried out on the abstracts made it possible to identify the main themes dealt with in the sample, which were used to identify inclusion and exclusion criteria useful for a further future systematic review of the literature on the subject.

Despite the numerous studies applying LCA in the agri-food and olive-growing sectors, as already mentioned, LCA per se is not considered a tool for circularity (Peña *et al.*, 2021) but can be supportive in defining the environmental performance resulting from circular strategies (Saade *et al.*, 2022; Samani, 2023). Thus, more in-depth analysis is required, assessing whether the metrics stated in the abstract or among the keywords support circularity. Therefore, the screening process should focus on metrics that measure or support the measurement of CE as well as the assessment of sustainability.

A further aspect to consider is the strong link between CE and waste, which emerges during the thematic and the Keywords Plus analysis. Thus, many of the circularity studies in the sample are probably focused on waste valorisation through material recovery or recycling strategies. This will likely leave out highly circular but intangible strategies such as awareness and inclusiveness (UNI, 2022). Therefore, it would be interesting to explore this aspect further, e.g., by classifying the metrics identified based on the principles of circularity, to delve into how and where circular value is generated.

Furthermore, apart from a few references to the environmental sphere in the thematic analysis, there are no direct references to the social and economic sphere of circularity. CE is closely linked to sustainability, as the network analysis confirmed, sharing economic and social objectives. Investigating the presence and characteristics of metrics to monitor these two aspects is crucial for the circular model to take root. Therefore, exploring the nature of metrics, as well as the presence of metrics that satisfy the all-round circularity is of paramount importance in future studies on the topic.

Conclusion

The present analysis performed a bibliometric analysis on 175 publications reporting CE assessment metrics examples in literature for the AFS, with particular attention to the olive oil supply chain. The analysis revealed that the interest in the topic is increasing exponentially, although there is a slight decline in 2023. Moreover, the highest number of publications is related to journals covering a broad range of sustainability aspects despite the analysis focusing on a specific context. Analyzing the top 10 authors who published in this field, just one published a study on the topic before 2020, while the highest contributions date back to 2022, as the highest number of citations. Europe is the most relevant player on this tune, and Italy is a leader among European countries. Such relevance is in line with the numerous interventions at the European and country levels to foster circularity. Focusing on the documents, the author's keywords analysis revealed CE and sustainability as most relevant, as well as LCA. Again, analysing Keywords Plus, the role of LCA is evidenced, together with waste and management. However, LCA does not assess the level of circularity but is a relevant method to assess CE impact. Thus, it is necessary but not sufficient to capture circularity. Finally, the thematic analysis performed on the articles' abstract evidenced the largest cluster, the one including circularity and the agri-food supply chain, set in the search criteria. This is followed by, on motor trends, the cluster including LCA as a method to measure the environmental impacts with several applications on the olive oil through the valorisation of olive pomace.

The present study provides a clear and detailed picture of the current CE assessment in the AFS, with particular attention to the olive oil supply chain. Nevertheless, the present study has some limitations, first related to the choice to focus only on peer-reviewed literature, cutting off possible metrics available in grey literature, and second, the section of just one, despite an exhaustive, database for the analysis.

Future studies could conduct a systematic literature review, based on the criteria emerged through the present bibliometric analysis. Moreover, this study is focused on scientific literature but is crucial to test the applicability of the metrics identified on companies of the sector, to understand if they can capture companies' necessities. This study provides a preliminary analysis but gives some relevant insights on circularity metrics in the AFS and olive oil industry. Some of the literature gaps highlighted here could be the starting point for additional investigation in CE assessment in the agri-food context for future contributions.

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From Paradigm to Practice of Circular Economy in Iberoamerica: Is Still an Aspiration for the Future or a Reality in SMES?

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Abstract

The Circular Economy (CE) paradigm has emerged as a prominent strategy for achieving sustainable development, mitigating climate change, and addressing pollution from linear production systems. Governments worldwide, including those in Iberoamerica, have enacted policies to promote CE, as evidenced by Spain's Circular Economy Policy, Colombia's Green Growth Policy, and similar initiatives in Ecuador, Chile, and Uruguay. However, a crucial question remains: Has CE become a reality, or is it still an aspiration for the future? The present study addresses this question by evaluating the implementation of CE in 57 Iberoamerican small and medium-sized enterprises (SMEs) across various fields of action, including resource procurement, product design and manufacturing, distribution and logistics, resource recovery, and industrial symbiosis. Data was collected between August 2019 and November 2023 through an online diagnostic tool that assesses six CE fields of action. The findings reveal that SMEs, as key players in this transition, have incorporated circular practices, particularly in the areas of "Take" and "distribution". However, the analysis by sectors indicates varied levels of adoption. Finally, the research uncovers opportunities for inter-company collaboration, new business models, and job generation, highlighting the significant role of SMEs in the implementation of the Circular Economy.

Introduction

Over the past decade, the Circular Economy (CE) paradigm has gained significant attention as a viable strategy for achieving sustainable development and mitigating the risks associated with climate change and prevalent polluting production systems. According to Prieto-Sandoval *et al.* (2018), CE is an economic system that aims to reintroduce materials and energy into multiple value chains, thereby reducing waste and promoting sustainability. It operates on various levels, from the macro to the micro, and requires a cyclic and regenerative innovation mindset.

Meanwhile, SMEs are a major economic force, making up a significant portion of businesses and employment. Over 99% of firms in the European Union are SMEs, cover two-thirds of total employment and are responsible for half of the value added in the market. (European Commission, 2022). According to the OECD, SMEs account for approximately 70% of total jobs and generate more than half of the value added in the business sector within OECD countries. In addition, SMEs often have greater flexibility and agility than larger firms, allowing them to adopt circular business models and practices (Gennari, 2023).

In the CE paradigm, SMEs have several opportunities to achieve greater sustainability through CE implementation in one or several of the six principal fields of action of the CE, namely: take, make, distribute, use, recover, and industrial symbiosis (Jaca *et al.*, 2019). In the field of **take**, which refers to how firms take resources and energy from the environment, SMEs should try to be more efficient and

responsible about using biological and technical resources and integrate environmental criteria in procurement to enhance sustainability (Harris *et al.,* 2021; Revell *et al.,* 2010). Nevertheless, SMEs need guidance to understand the value of CE and how to implement it in their strategies. (Ormazabal *et al.,* 2020). Regarding make, which is associated with the process of designing and creating products and services, CE practices imply eco-innovation that improves the process, product, and service. This field would be enhanced according to the SMEs' environmental management maturity and context. (Katz-Gerro and López Sintas, 2019).

The distribution, in turn, is related to every initiative dedicated to improving the firm's packaging, distribution and logistics to reduce the environmental impact. In this vein, research on sustainable logistics highlights the importance of route optimisation and efficient packaging in reducing the ecological footprint of SMEs (Kumar & Malegeant, 2006). The field of use or consumption revealed the impact of the products and services in the consumer's hands, such as energy consumption, maintenance, water spending, etc. Harris *et al.* (2021) suggest that further research is needed to assess the use phase, as it is less understood than other CE processes. As for the recovery field, it considers every eco-innovation effort to get value from the waste, materials, and energy that remain in used products at the end of their lifecycle. In this way, some studies discuss the role of SMEs in the CE and the need to design products with end-of-life in mind to enhance recycling and biodegradability (Ghisellini *et al.,* 2016). Finally, industrial symbiosis represents a collaborative supply chain management strategy based on Chertow's (2000) definition of an industrial ecosystem with symbiotic relationships among industries facilitated by geographical proximity. Thus, “A successful transition to a CE paradigm requires an industrial metabolism to close the loops through different value chains” (Prieto-Sandoval, Ormazabal, *et al.,* 2018). In SMEs, industrial symbiosis represents an opportunity to take advantage of by-products, idle infrastructure, and reverse logistics, among other benefits.

Given that the CE model has emerged as a powerful tool for sustainable development, many governments have enacted policies to promote the CE alongside compatible economic strategies like industrial symbiosis, bioeconomy, and blue economy. Fortunately, Iberoamerica is also charting a course toward this paradigm shift, evidenced by legislative frameworks like Spain's Circular Economy Policy, Colombia's Green Growth Policy, Ecuador's White Book, Chile's Circular Economy Office, Uruguay's Biovalor project, and others. In addition, intergovernmental organisations encourage the creation of eco-industrial parks, such as the UN-led global program, and cleaner production centres that support local initiatives. The policy framework paves the way for CE implementation, but it is not a guarantee. Then, based on environmental awareness and knowledge, the consumer's demand creates the press to push firms to offer innovative and circular products and services. In this context, this study posed the next research question: Has the CE become a reality in Iberoamerica, or is it still an aspiration? What are the strengths and weaknesses of SMEs in the implementation of CE? Are there any differences between sectors?

Intending to address the aforementioned questions, this study evaluates the implementation of CE in 57 Ibero-American SMEs across the CE fields of action. These fields encompass resource procurement, product design and manufacturing, distribution and logistics, resource recovery, and industrial symbiosis. Data was collected between August 2019 and November 2020 utilising an online diagnostic tool designed by Jaca *et al.* (2019) to evaluate adherence to the six core CE fields. The contribution of this work is twofold. First, this study contributes to the literature on CE implementation in IberoAmerican SMEs.

Second, it provides new information about Iberoamerican consumer behaviour, which identifies new business opportunities for those designing new CE business models.

The paper is structured as follows: Section 2 presents a literature review that links the CE relevance with the potential development in the region. Section 3 explains the methodology used to develop the study. Then section 4 shows the results and their discussion, and Section 5 presents the study's conclusion.

Literature Review

CE, as a strategy to achieve sustainable development, requires models that allow its implementation effectively from a particular perspective. There are different proposals for these models, such as the Butterfly Diagram. (Ellen MacArthur Foundation, 2013) that visualizes the implementation through the closing of biological and/or technical cycles. From another point of view, the ReSOLVE framework aims at the execution of certain circular practices belonging to different categories (Arup; The Ellen MacArthur Foundation, 2016). Finally, the Fields of Action of CE model (Jaca *et al.*, 2019), proposed by the Tecnun team at the University of Navarra (Spain), is based on the analysis of the various stages of the product life cycle.

This last model is characterized not only by following the product life cycle but also by incorporating a strategic vision of the CE which creates a competitive advantage in companies (Prieto-Sandoval *et al.,* 2019). Also, for considering new circular practices as eco-innovations (Kemp and Pearson, 2007) that influence organizations' strategies. Likewise, this model incorporates industrial symbiosis as a transversal field of action that connects the company with the organizational ecosystem that surrounds it.

Regarding to eco-innovation, it is considered one of the axes of the change towards circularity by grouping all the novel and valuable actions with a strategic sense that the organisation develops. Thus, eco-innovations group new processes, techniques, practices, systems and products designed to solve the needs of humans and nature within a balanced framework. (Hofstra and Huisingh, 2014). Kemp and Pearson (2007) state that eco-innovation is the production, application or exploitation of a good, service, production process, organisational structure, or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resource use (including energy use) compared to relevant alternatives. Thus, these eco-innovations can be presented as a mix of actions on the various fronts of the organisation, which affect its value proposition towards customers and other interest groups. For this reason, it can be said that there are eco-innovations that change the business model, making it much more circular. Consequently, this mix of eco-innovations implements circular business models, according to Rosa *et al.* (2019), are a new type of business model where value creation is based on maintaining the economic value embedded in products after their use and their exploitation for new types of market offerings.

From another point of view, the transversal field of action of Industrial Symbiosis (IS) is another crucial point in this model, because it can be particularly useful in fostering a CE in SMEs. Business associations (BAs), clusters, and inter-organizational units can significantly facilitate this process (Prieto-Sandoval *et al.,* 2021). Multiple collaboration opportunities exist; for example, IS networks enhance sustainability from the supply chain perspective by utilising waste, by-products, and excess utilities between

independent industries (Herczeg *et al.,* 2018). In addition, "coordination in the IS network ensures long-term sustainability with strategic alignment. Incentive alignment between companies is facilitated by mutually shared interests for economic gains and reduced environmental impact." (Herczeg *et al.,* 2018).

IS can emerge spontaneously or be encouraged by different organisations. Spontaneous examples include natural collaborations formed due to geographical proximity or shared interests. Local stakeholders, such as regional authorities and business associations, can promote IS among SMEs by fostering partnerships and facilitating the CE. Case studies from Sweden demonstrate that economic gains and better environmental performance motivate companies to participate in these partnerships (Patricio *et al.*, 2018). Also, regional programmes such as the National Industrial Symbiosis Programme (NISP) in the UK increased knowledge and relational resources, promoting IS and supporting the transition to a CE (Abreu and Ceglia, 2018). Besides, digital tools help detect potential synergies and map IS networks (Álvarez & Ruiz-Puente, 2017) and facilitate the transition towards circular business models by effectively engaging stakeholders and promoting sustainable practices among SMEs (Caputo *et al.,* 2021).

Instruments such as business associations (BAs), clusters, and inter-organizational units are pivotal in facilitating IS among SMEs. These instruments not only support the operational aspects of IS but also contribute to the strategic integration of CE principles into SMEs' business models. For example, BAs serve as intermediaries that promote CE by fostering trust-based relationships, supporting collaborative innovation, and helping SMEs close material and energy loops (Prieto-Sandoval *et al.,* 2021). For instance, BAs can help companies identify potential partners for material exchanges, provide information on best practices, and offer a platform for sharing resources and infrastructure. Clusters, which are geographic concentrations of interconnected companies and institutions, can enhance the effectiveness of IS by promoting local synergies and resource sharing. Similarly, inter-organizational units, which operate across various firms, can facilitate the coordination and implementation of IS activities by providing specialised knowledge and technical support. (Prieto-Sandoval *et al.,* 2021).

However, some barriers persist, such as lack of awareness, limited financial resources, and regulatory challenges (Ormazabal *et al.,* 2020). However, there is potential for substantial progress in these areas with cooperative efforts, government support, and innovative strategies. Sustainable supplier selection is critical to achieving sustainable supply chains and applying industry 4.0 practices to tackle circular economy implementation Kusi-Sarponga (2021).

Methodology

This research adopts an exploratory diagnostic approach to examine the implementation of Circular Economy (CE) practices among SMEs in Ibero-America. Data collection was conducted through an online diagnostic tool, through key elements in assessing CE implementation in SMEs based on the six fields of action presented before (Prieto-Sandoval, Ormazabal, *et al.,* 2018). Then, the tool applied a 7point Likert scale (1 = lowest performance, 7 = highest performance) to evaluate CE implementation across six fields of action: take, make, distribute, use, recover, and industrial symbiosis. The data collection period spanned from August 2019 to November 2023, and a total of 57 companies from various economic sectors in Colombia, Spain, and Chile participated voluntarily. Only those firms with decision-making power across all six fields of action were included in the final analysis. Participation was voluntary and without financial

compensation, although companies that opted to contact the researchers received an executive summary of their results.

The analysis included companies from 15 different economic sectors, such as commerce, textiles, construction, and food, with 18% of these companies certified with a sustainability standard. Table 1 presents the distribution of participating companies by country, and Table 2 shows the company size by the number of employees. The overall performance of the companies was assessed, with 58% demonstrating good performance (scores of 5 to 7), indicating a commitment to sustainability (see Figure 1).

Table 1. Companies by Country

Country	Number of companies	Percentage
Chile	6	11%
Colombia	42	74%
Spain	9	16%
Total	**57**	**100%**

Table 2. Company size by number of employees

Number of employees	Number of companies	Percentage
Equal to or less than 10	24	42%
Between 11 and 50	21	37%
Between 51 and 100	9	16%
Between 101 and 250	3	5%
Total	**57**	**100%**

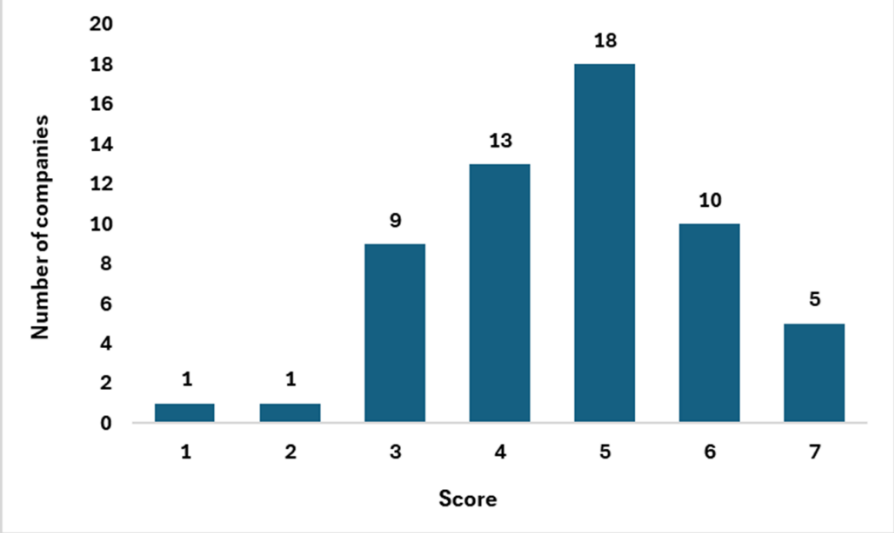

Figure 1. Companies by performance

Results and Discussion

Dominant Practices in SMEs

Table 3 reveals that "Take" and "Distribution and Logistics" exhibit the most advanced practices among the assessed CE action fields. In this last field of action, the highest scores in the survey are found. This shows that aspects related to transportation routing (4,25), the use of product storage capacity (4,84) and the design of packaging for logistics (4,23) are relevant topics for companies. Within the "Take" field, it is suggested that material and waste minimisation strategies are likely more sensitive to profitability improvements and require less implementation experience. (Katz-Gerro and López Sintas, 2019). Thus, SMEs demonstrate a moderate level of environmental purchasing criteria, with an average score of 4.26. This indicates that while some ecological considerations are integrated into purchasing decisions, there is significant room for improvement. Similarly, a score of 4.46 for raw material supply points towards a moderate effort by SMEs to reduce resource consumption of raw materials, water, or energy in production processes. However, the "Make" field paints a less optimistic picture, with practices related to extending the useful life of industrial resources receiving a low score of 2.95. This suggests that treatments for maximizing industrial resource utilisation are not widely adopted. Notably, SMEs appear to require further attention towards CE practices that address a product's environmental impact during its use phase and the potential for product-as-a-service models. The practices with the worst performance are related to using sustainable energy sources (1,88) and the recovery and use of energy from the heat generated in their production processes (2,12). This finding also aligns with those of Roper *et al.* (2020) who highlight the financial and informational challenges faced by SMEs when adopting renewable energy sources. Furthermore, these results resonate with Harris *et al.* (2021), who suggests that the impact associated with the "use" phase is less well-understood than other CE processes.

Table 3. Companies' performance by CE field of action

CE Field of Action	Question	Performance
Take	Do you have environmental purchasing criteria? (Buy recycled raw materials, certified products, etc.)	4,26
	Does the company have environmental criteria to reduce the consumption of raw materials, water, or energy in the design and improvement of its production processes?	4,46
	Does the company use sustainable energy sources such as solar, wind, or others?	1,88
	How much do you consider that the materials used in production are designed to be biodegradable?	3,40
	How much do you consider that the NON-biodegradable materials used in production are designed for re-use, recycling or re-manufacturing?	4,09
Make	Does the company use treatments (filtering, soaking, etc.) to extend the use of industrial resources such as oils, acids, lubricants, etc.?	2,95
	Do you promote or provide some maintenance manual to extend the useful life of your products?	3,75
	Does the company offer after-sales repair services that extend the life of the products?	4,33

CE Field of Action	Question	Performance
Distribution and Logistics	Rate from 1 to 7 if they take into account the environmental impact when choosing the routes used to transport the product	4,25
	Should the logistics of transporting the product be considered when designing your packaging? (For example, changing the dimensions of the container may mean carrying more product in the truck)	4,23
	Are the means of transport used saturated to carry the maximum permitted product?	4,84
Use	Does the company offer any product rental services for a defined period?	2,61
	Are your products designed to use renewable energy during operation? (Example: solar calculator)	2,26
Recover	Does the company recover and use energy from the heat generated by its plant?	2,12
	Does the company recover products that its customers no longer use?	3,42
	Does the company market the industrial material it generates (chemical byproducts, oils, packaging, plastics, etc.)?	3,39
	Are your products ready for refurbishment or upgrade?	3,49
	Is it financially feasible to participate in recovery activities?	4,14

1: Lowest performance **7: Highest performance**

Table 4 shows no significant performance difference in "Industrial Symbiosis" between SMEs affiliated with and unaffiliated with Business Associations (BA). Nevertheless, while BA-affiliated SMEs demonstrate a higher propensity for sharing physical infrastructure and co-creating products, a seemingly contradictory finding emerges: unaffiliated SMEs exhibit a greater tendency to share byproducts and valuable waste. This aligns with Lee and Klassen (2008), who argue that "for large suppliers, collaboration with, instead of one-way support from, buyers is a more relevant and common way to improve their EMC in the context of the supply chain, similar to collaboration between buyers and suppliers in environmental innovation (e.G, Geffen and Rothenberg 2000, Grant and Baden-Fuller 1995" Notably, such collaboration can occur outside formal industrial symbiosis structures. Therefore, this study highlights the presence of inter-firm collaboration, albeit informal in nature regarding BA or cluster affiliation. This underscores an opportunity for policymakers to facilitate and strengthen these material exchange flows. By leveraging the collective capabilities and resources of BAs, clusters, and inter-organizational units, SMEs can overcome common barriers to CE adoption, such as lack of expertise, financial constraints, and limited access to information.

Table 4. Industrial symbiosis performance among companies

Variable	Affiliated to Business Association		
	No	Yes	Total
Number of companies	39	18	57
Does the company share infrastructure, machinery, or services with other companies?	3,2	4,3	3,6
Does the company collaborate to create or develop products or services?	4,1	4,8	4,3

Variable	Affiliated to Business Association		
	No	Yes	Total
Does the company use any surplus or waste from another company in its process or activities?	3,5	1,9	2,98
General performance	3,6	3,7	-

1: Lowest performance **7:** Highest performance

The Industrial Sectors with the most Progress in CE Adoption

An evaluation of CE adoption among SMEs reveals variations across the sectors, as detailed in Table 5. The average performance ratings provide insights into how effectively various industries embrace CE practices. While some sectors demonstrate a noteworthy level of CE adoption, significant variability exists. In fact, the *media, culture, and graphics* sector leads in CE adoption, with the highest rating (4.4), indicating a strong commitment to and integration of CE practices. Conversely, sectors like *base metal production* (1,9) and utilities (2,7) with the lowest scores indicate that they require more focused efforts to improve their practices, suggesting substantial challenges or a lack of CE implementation.

Table 5. CE adoption by economic sectors

Economic sector	Average score
Media, culture, graphics	4,4
Postal and telecommunications services	4,1
Financial services, professional services, consulting	4,0
Chemical industries	3,8
Construction	3,7
Civil service	3,7
Textiles: clothing, leather, footwear	3,6
Agriculture, plantations, other rural sectors	3,5
Food, beverages, tobacco	3,5
Education	3,3
Health services	3,2
Commerce	3,1
Mechanical and electrical engineering	3,1
Utilities (water, gas, electric)	2,7
Base metal production	1,9

1: Lowest performance **7:** Highest performance

Governments and Institutions Support CE Adoption

Recent advancements in regulations and the emergence of potential pathways at the macro level represents an invitation to assess how firms perceive government support for the transition to a CE. However, as shown in Table 6, the average rating for government support across various sectors is only 2.4 out of 7, suggesting a relatively low level of satisfaction among firms. Therefore, it is expected that the

government provide more infrastructure and financial support to the SMEs to facilitate their transition to the CE.

Table 6. Government support for CE adoption by economic sectors

Economic sector	Average score
Chemical industries	4,5
Health services	4,0
Education	3,0
Food, beverages, tobacco	3,0
Utilities (water, gas, electric)	3,0
Agriculture, plantations, and other rural sectors	2,5
Commerce	2,2
Mechanical and electrical engineering	2,0
Media, culture, graphics	2,0
Base metal production	2,0
Financial services, professional services, consulting	1,6
Construction	1,0
Civil service	1,0
Textiles: clothing, leather, footwear	1,0
Postal and telecommunications services	-
Average	**2,4**

1: Lowest performance **7:** Highest performance

Likewise, our findings reveal significant disparities in companies' perception of government support for the transition to the CE across different industries in Ibero-American SMEs. In fact, for instance, the highest scores observed in the Chemical Industries (4.5) and Health Services (4.0) sectors suggest a considerably higher level of support for these industries compared to Construction (1.0) and Textiles (1.0), which received the lowest ratings. These findings imply that while some sectors perceive moderate government support, the overall companies' perception indicates insufficient efforts, particularly regarding SME implementation. This highlights the need for enhanced and targeted government initiatives to promote CE adoption across all sectors. Postal and telecommunications services were not assessed.

Conclusion

Our exploratory diagnostic study of CE implementation in 57 Iberoamerican SMEs reveals a mixed reality. It identifies discrepancies between firms' priorities and their performance across different CE fields of action. Notably, the study finds that many SMEs have begun incorporating CE practices in the "Take" and "Distribution" fields. These practices include utilizing recycled materials, optimizing resource consumption, and improving packaging and transport efficiency. It is particularly interesting to note that SMEs demonstrate a moderate level of environmental criteria in procurement and efforts to reduce raw

material consumption, which can lead to cost savings. However, the adoption of most CE practices related to the "Make," "Use," and "Recovery" fields within firm processes remains largely aspirational.

The findings regarding industrial symbiosis implementation present a paradox. While empowering industrial symbiosis through business associations, clusters, and inter-organizational units is crucial for increasing CE adoption in SMEs, the analysed SMEs are not currently leveraging these organisations. These entities facilitate collaboration, enhance institutional capacity, leverage digital tools, and help overcome barriers, ultimately leading to sustainable industrial practices and improved resource efficiency. This lack of utilization by SMEs hinders the potential flow of materials and information necessary for CE adoption. Thus, the facilitation of industrial symbiosis is essential for advancing the circular economy in SMEs. Their role in promoting collaboration, supporting, and enhancing resource efficiency underscores their importance in driving sustainable development.

This study offers valuable managerial implications for policymakers seeking to accelerate the integration of SMEs into circular business models and industrial symbiosis systems. By understanding the current state of CE adoption across different sectors, policymakers can design targeted policies that create an enabling environment for SME participation in the circular economy. While service sectors show promise with medium-high performance, SMEs in manufacturing sectors require significant support to capitalize on CE opportunities throughout the product lifecycle, encompassing design, production, use, and material recovery. Sectors like construction, textiles, and agro-industry show substantial progress in adopting CE principles. However, others, such as base metal production and utilities, require more focused efforts. Notably, the transition to sustainable energy systems remains a major challenge for most SMEs.

This research also identifies critical information gaps that require further investigation by public institutions. Access to comprehensive data, including macroeconomic statistics on the CE, specific implementation challenges faced by SMEs, and trends in job creation and materials innovation, would enable a more comprehensive diagnostic analysis of the region's progress towards a CE. Consequently, a deeper exploration of potential barriers, such as investment constraints, knowledge gaps, and time limitations experienced by SMEs, is crucial for informing targeted policy interventions and facilitating improvements.

Finally, this study acknowledges it has some limitations. First, the absence of a comprehensive public database integrating information across Iberoamerica, or a dedicated regional agency. This limitation was faced by using date collected through the online tool developed by Prieto-Sandoval, Ormazabal, *et al.* (2018). Second, the unwillingness of firms to share sensitive information limited the analysis to data collected via a Likert scale. This limitation could potentially be overcome by establishing confidential agreements with companies, though such agreements would depend on individual companies' interest and commitment to sustainability. Third, business associations currently lack the influence necessary to fully integrate businesses into a circular metabolic system, further exacerbated by low firm participation within these associations. So, government incentives could potentially encourage greater company involvement. Finally, the relatively small number of analysed companies limits the generalizability of our findings. We are actively collecting additional data to build a more robust database and facilitate the generation of more conclusive results.

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Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Assessing Circularity in the Agri-Food Sector: A Case Study

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Abstract

The agri-food sector (AFS) faces challenges in providing affordable and healthy food for an increasing population. In this context, Circular Economy (CE) has gained interest as an approach to drive the food system to sustainability. However, circularity does not always lead to sustainability. The lack of a defined set of metrics to monitor CE in the sector makes it relevant to select assessment approaches that capture CE's contribution to sustainability. For this reason, the present study aims to support the dairy cooperative Fattoria della Piana, a best case of CE, in assessing its circular strategies. The study links Life cycle assessment (LCA) with circularity indicators collected in the literature. This preliminary study analyses the core of the circular exchanges of the cooperative, represented by the anaerobic digestion and combined heat and power plant (AD-CHP) plant. The study presents a valuable assessment approach for companies in the sector, highlighting the complexity of assessing CE. LCA evidenced valuable credits from avoiding mineral fertilizer and natural gas use thanks to their substitution with the treatment plant's outputs. Indicators suggest its ability to recirculate waste for energy purposes and nutrients. Future studies will explore the overall cooperative' system, evaluating the three dimensions of sustainability.

Introduction

Dairy products provide an essential source of nutrients; however, their intensive production and consumption contribute to environmental and health challenges (Stanchev *et al.*, 2020). Indeed, improper management of sewage and manure severely contributes to climate change and reduces biodiversity, threatening human health (Zhang *et al.,* 2021). Finding a sustainable venue for the sector is central to reducing its environmental footprint along the entire supply chain (Stanchev *et al.*, 2020). This brought attention to the Circular Economy (CE) model. Despite CE being widely explored in the dairy sector, the full recirculation of resources and waste is still far (Stanchev *et al.*, 2020). Thus, it is necessary to monitor how much the circular strategies implemented in the sector contribute to sustainability. Circularity metrics should support companies' decision-making in implementing efficient circular strategies in their businesses. Nowadays, the multitude of metrics available of the AFS makes selecting appropriate tools challenging for companies, limiting the quality of the information provided (Kounani *et al.*, 2023). The relevance of CE brought to the publication of relevant standards; at the national level, the UNI/TS proposed a set of indicators for CE assessment at the organizational level (UNI/TS 11820:2022); at an international level, the ISO published the ISO 59000 series, which standardized CE definition, application and assessment (ISO/FDIS 59020). However, the AFS deals with organic materials which dissipate after

use (Møller *et al.*, 2023) and neither of the standards is sector specific. Thus, empirical studies applying CE metrics are relevant to identify metrics able to support circularity. Some studies observed that circularity should be monitored through a combined approach using LCA together with circularity indicators (Rigamonti and Mancini, 2021; Rufí-Salís *et al.,* 2021; Niero and Kalbar 2019). In this context, the present study aims to support companies of the AFS in assessing and monitoring the circularity and sustainability of their strategies. To this end, the study adopts a case study analysis of the dairy cooperative Fattoria della Piana. The cooperative represents a best case of circularity and industrial symbiosis for the South of Italy, which was awarded as a sustainable company (Impresa sostenibile) by the Sole 24 Ore (Il Sole 24 Ore, 2023). Moreover, the study was conducted within a six-month collaboration with Fattoria della Piana contemplated as an internship within the PhD scholarship PON No. 2. This allowed the collection of primary data through surveys and interviews onsite, increasing the reliability of data. Within the cooperative system, the Anaerobic Digestion and Combined Heat and Power (AD-CHP) plant has a central role in the symbiotic exchanges within the cooperative supply chains and other local businesses, contributing to closing the loop of waste and resources. For this reason, the present preliminary study focuses on the AD-CHP plant, exploring the circular strategies entailed.

System Description

Fattoria della Piana is a dairy cooperative in the province of Reggio Calabria (Italy) that closes the loop of resources and waste in its dairy chain. The cooperative has embodied CE's principles, generating symbiotic exchanges among the various supply chains and partners companies; The agricultural supply chain allows the company to produce on site a large part of the fodder for the livestock, using digestate produced via AD instead of mineral fertilizer on the fields. The breeding phase produces cattle milk for the cheese factory but also produces manure and sewage as waste which is then pumped to the treatment plant and used as input for the AD process. Moreover, in terms of energy, a photovoltaic system placed on the roof with a nominal power of400 kW, inclined at 14° facing South, provides electricity to the farm (https://fattoriadellapiana.it/). The cheese factory uses as input the cattle milk produced internally, plus sheep and goat milk provided by the Pastori Calabresi, who are partners of the cooperative. The heat used in the cheese production is generated by the AD-CHP plant, while the factory delivers whey, a subproduct of cheese production, to the treatment plant and delivers wastewater to the Phytodepuration plant. The cooperative also collects waste from partners companies which are in the neighborhood (main exchanges entail olive pomace and agrums pulp) providing back digestate to be used as organic fertilizer. Thus, the cooperative through the AD-CHP plant generates a self-sufficient ecosystem, where waste is turned into a resource and networking operations take place. This allows both to reduce the cost associated with the treatment of such waste and reduce the cost of e.g., providing heat, nor electricity to the system and reducing the environmental impact of the cooperative. Figure 1 summarizes the main exchanges within the system, which includes: Fattoria della Piana (the owner of the cheese factory, of one of the treatment plants, and of part of the distribution chain), Uliva (which deals with the breeding and agricultural productive chain and of one of treatment plants), Pastori Calabresi (a cooperative made of shepherds and agricultural producers of olives and citrus fruits), and Arriva fresco (which deals with the distribution activities).

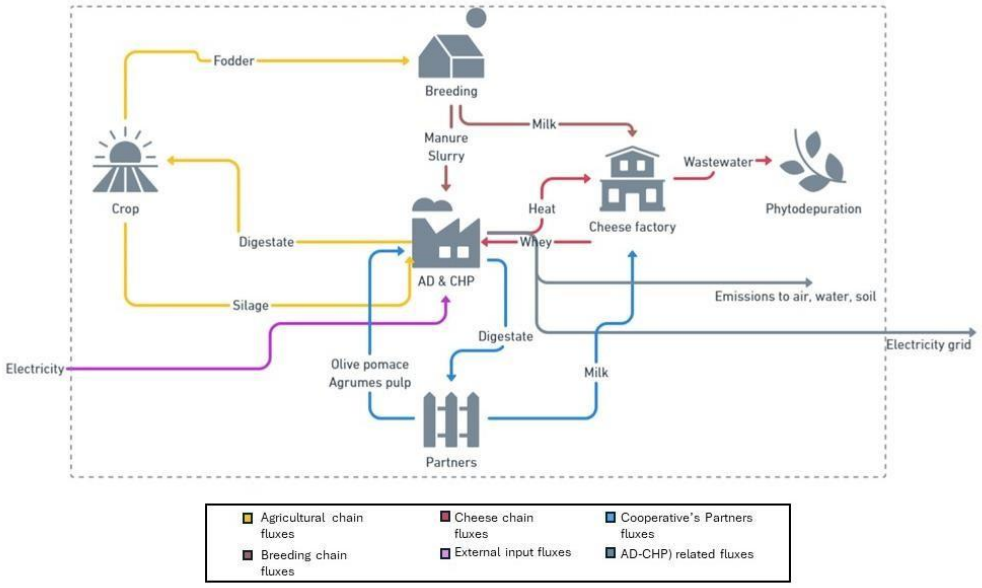

Figure 1. Main fluxes of the cooperative system. Source: own elaboration from data collected at "Fattoria della Piana".

The Anaerobic Digestion and the Combined Heat and Power Generation (AD-CHP) Plants

The AD-CHP treatment process consists of two main phases: i) anaerobic digestion, during which microorganisms decompose organic materials in a de-oxygenised space, producing biogas and digestate; ii) biogas reaches the Combined Heat and Power plant where it becomes electricity and thermal energy (Chowdhury, 2021). The cooperative has two equal AD-CHP plants with an electrical power of 998 kW each. The treatment plants are owned by Fattoria della Piana (plant a) and by Uliva (plant b). Plants are fed with internal waste, i.e. silage residues of wheat and corn, manure, sewage and bedding residue and whey. Additionally, the plants receive from external partners' inputs such as olive pomace, citrus pulp, molasses and chicken manure. All data here provided are primary information collected on site. In detail, in 2022 plant a) produced 5,342 ton of biogas, 2,779 ton of solid and 31,954 ton of liquid digestate. In the same year, plant b) produced 5,342 ton of biogas, 2,660 ton of solid and 30,594 ton of liquid digestate. Then biogas is burned in the CHP plant to produce electricity and thermal energy.

Methodology

To support companies of the AFS in circularity assessment, the present study proposes a case study analysis. This analysis allows us to explore an exemplary case of circularity applied to the dairy supply chain, grasping all the exchanges occurring among the various actors of the system in their original context (Eisenhardt, Graebner, & Sonenshein, 2016). The methodological approach chosen to assess the environmental profile and circularity of the AD-CHP plant is based on LCA and CE indicators. LCA defines the environmental load linked to the implementation of CE, while CE indicators measure the circularity of the system under analysis. Most of the data were collected at the company by administering surveys and

conducting interviews with the cooperative's management and employees, while background or missing data were collected from scientific literature and databases.

CE Indicators

To assess the level of circularity of the treatment plant, some circularity indicators available in the literature and in line with the characteristics of the system under analysis were selected. Specifically, the following studies were considered in the selection process: i) Mancini and Raggi (2021), who explored the role of AD processes evaluation and assessment; ii) Poponi *et al.* (2022), who collected all the CE indicators available in literature, creating a dashboard; iii) Kounani *et al.* (2023), who collected CE indicators suitable for the olive oil supply chain; iv) Feiz *et al.* (2020), who selected indicators appropriate for the comparison of different biogas production contexts. The indicators selected concern the most critical aspects of the system analysed, namely energy, nutrients and organic waste, which were adapted to the case study context and presented in Table 1.

Table 1. CE indicators selected

Indicator	Description	Reference
Biogas efficiency	Energetic revalorization of waste	Mancini and Raggi (2021) Feiz *et al.* (2020)
Energy balance	Energy delivered (biogas) on primary energy of the process	Feiz *et al.* (2020)
Nitrogen recycling potential	Percentage of nitrogen recirculated in the system	Feiz et al. (2020)
Energy self-sufficiency	Capability of the system to cover its energy needs	Poponi *et al.* (2022) Kounani *et al.* (2023)

LCA Modelling

To assess the environmental profile of the AD-CHP plant, LCA is adopted according to the ISO 14040 and 14044 methodological guidelines (ISO 14040:2006/Amd 1:2020; ISO 14044:2006/AMD 2:2020). The analysis aims to define the environmental profile of the AD-CHP plant by measuring the potential environmental impacts through LCA, including avoided productions, thus including environmental credits associated with the avoided production of conventional fertilizers and natural gas. The treatment plant uses cattle sewage and manure (from the livestock phase), olive pomace, agrums pulp, chicken manure and molasses (from partners), corn and wheat silage (from fodder production), and cheese whey (from the cheese factory) as process inputs. The FU adopted is 1 MWh of electricity produced by the system, while the system boundaries allow a "gate to gate" perspective of analysis. Some cut-off criteria are included: i) no environmental impact is considered for cattle manure and sewage being wastes of the livestock supply chain; ii) the production of machinery, equipment and infrastructures is excluded from the study since the production of such capital is not significant in a life cycle context (Salomone and Ioppolo, 2012). To conduct the analysis, primary and secondary data were collected. Primary data relate to the 2022 productive year and report information regarding inputs (such as feedstock, electricity, and heat) and outputs (such as biogas, digestate, heat and electricity). These data were provided by the cooperative management and employees working on or with the treatment plant unit. Secondary data based on scientific literature and databases were used to fill in missing and

background data, e.g., data on the plant production activity and electricity generation, were extracted from Ecoinvent (Wernet *et al.*, 2016). The treatment plant produces biogas and digestate, where the latter is then used by the cooperative as organic fertilizer in the agricultural supply chain and sent to partners who contribute their waste to the activity of the treatment plant. Following the ISO recommendations, the present study avoided the allocation process by adopting the substitution method, by including the avoided production of conventional production of heat and fertilizers. The heat produced in the treatment plant fulfils the needs of the treatment plant and the cheese factory. Thus, the heat produced by the system replaces the heat produced by conventional sources, e.g., natural gas produced by considering the reference linear scenario given the characteristics of the system. This implies that the environmental load related to the avoided heat can be considered a credit for the system, where the eco-profile of natural gas is derived from Ecoinvent (Wernet *et al.*, 2016).

Moreover, the study considers the digestate and the emissions connected as a replacement for conventional fertilizer. Thus, the environmental impacts associated with mineral fertilizer account for credits of the system. The LCA analysis is performed using SimaPro 8 software (PreConsultant, 2010), selecting appropriate impact categories and connected characterization factors. The methods used to estimate the environmental impacts of the plant are: i) CML IA baseline V3.07 (CML - Department of Industrial Ecology, 2016) method, selecting as impact categories abiotic depletion, abiotic depletion (fossil fuels), ODP, Human Toxicity, Freshwater aquatic ecotoX, Marine aquatic ecotoxicity, Terrestrial ecotoxicity, Abiotic Potential, Eutrophication Potential, and POFP; ii) IPCC 2021 GWP100 method (IPPC, 2021) which allows to evaluate the Global Warming Potential (GWP100); and iii) Cumulative Energy Demand (CED) to assess the total primary energy requirement, originated along the life cycle (Frischknecht *et al.*, 2007), adding impact category.

Results and Discussion

Inventory Data for Inventory Data for the AD-CHP Plants

The AD plant produces biogas and digestate. The biogas has 55% methane content for the volume of biogas produced, while the remaining portion is assumed to contain only CO_2 (Giuntoli *et al.*, 2017). Nevertheless, a small portion of biogas is lost, and the uncontrolled emissions represent >5% of biogas yield. The digestate is considered a co-product of the treatment plant. Specifically, digestate is moved from the digester to open tanks and then used as organic fertilizer without additional processing stages (Cusenza *et al.*, 2021). The open storage generates emissions of Nitrous oxide (N_2O) and methane (CH_4) caused by the residual organic matter content. Secondary data from the literature is used to estimate such emissions (Fusi *et al.*, 2016; Reichhalter *et al.*, 2011). Finally, the system considers the environmental credits associated with the prevention of production and use of mineral fertilizer, mainly composed of urea; thus, mineral fertilizer is considered a function of the amount of nutrients present in the digestate produced (Lijó *et al.,* 2014). Following Reichhalter *et al.* (2011) and Sedorovich *et al.* (2007), the avoided emissions associated with the conventional management of 1 tonne of cattle sewage and manure are 4.10 kg of CH_4 and 0.10 kg of N_2O per m^3 in a year. The CHP plant produces thermal and electric energy. Data on the emissions associated with the combustion process are based on secondary data and the macro-pollutants considered are nitrogen oxides and methane. The inventory data expressed per FU is reported in Table 2.

Table 2. Inventory data for AD-CHP plant's operation represented per 1 MWh of electricity produced

AD-CHP Plant	Unit	Amount	Data source
Input	t		
Bovine manure		3.76E-01	Primary data
Bovine slurry	t	2.35E-01	Primary data
Poultry manure	t	3.14E-01	Primary data
Whey	t	8.35E-01	Primary data
Silage waste	t	1.29E-01	Primary data
Olive pomace	t	2.89E+00	Primary data
Citrus pulp	t	1.68E+00	Primary data
Molasses	t	2.89E-02	Primary data
Electricity	kWh	2.94E+00	Primary data
Heat (from CHP)	kWh	1.16E+02	Mistretta *et al.*, 2022
Output			
Biogas	Nm^3	5.19E+02	Primary data
Electricity	kWh	1.00E+03	Primary data
Heat	kWh	2.76E+02	Mistretta *et al.*, 2022
Solid digestate	t	3.27E-01	Primary data
Liquid digestate	t	3.76E+00	Primary data
CO_2, biogenic	t	1.15E+00	FIPER, 2018
NOx	t	2.34E-04	FIPER, 2018
CH_4, biogenic	t	1.40E-02	FIPER, 2018
Heat waste	kWh	2.06E+01	Primary data
Avoided products Heat	kWh	1.58E+01	Calculated data
Mineral fertiliser	t	2.76E-01	Calculated data

CE Indicators

The biogas efficiency indicator (KPI_1) (Mancini and Raggi, 2021; Feiz *et al.*, 2020) monitors the energy valorisation of organic waste, by calculating the biogas generated during the AD process on the amount of organic waste used as input in the process. In this case, only organic waste was included in the system, thus the calculation was simplified focusing on just one type of waste (Salguero-Puerta *et al.*, 2019). As indicated in Table 3, the I_{bce} is 43.99 m^3 CH_4 /ton of waste. This indicates that every tonne of organic waste generated produces 43.99 m^3 CH_4 /ton of waste. This quantifies the valorisation of waste in terms of energy, but also suggests the efficiency of waste management within the system. Higher values suggest better performances for the system.

Table 3. KPI_1 calculations

Input	Value	Unit
Biogas produced	4.41E+06	m^3
Methane % in biogas	5.50E+01	%
Methane produced	2.43E+06	m^3CH_4
Waste collected	5.52E+04	ton
Ibce	4.40E+01	m^3 CH_4 /ton

The energy balance indicator provides an information regarding the energy performance of the biogas produced out of organic waste; it is given by the amount of energy produced as biogas on the amount of primary energy utilized to generate and distribute the same energy. The calculations are shown in Table 4.

Table 4. KPI_2 calculations

Input	Value	Unit
Biogas delivered	4.41E+09	m^3
Biogas lost	2.21E+09	m^3
Methane in net biogas	2.31E+09	m^3
KPI	1.91E+09	m^3

The self-sufficiency indicator (KPI_3) measures the self-sustaining capacity of the treatment plant as suggested in the literature (Poponi *et al.*, 2022; Kounani *et al.*, 2023). This is given by the energy produced and re-used by the treatment plant on the total amount of energy required by the plant for its functioning. In this case, the internal production of thermal energy and the electricity deriving from the electricity grid was considered. The AD-CHP plant of Fattoria della Piana covers 97.5% of its own thermal energy needs by the self-produced energy.

Digestate contains several macronutrients which are crucial for plant growth; the main ones are nitrogen (N), phosphorus (P) and potassium (K); using digestate as organic fertilizer allows for the recycling of such macronutrients (Feiz *et al.*, 2020). Thus, the nitrogen recycling potential (KPI_4) is chosen to verify the system's ability to recirculate nitrogen (Møller *et al.*, 2023; Feiz *et al.*, 2020). The indicator considers the quantity of nitrogen in the digestate and the quantity in the type of waste used as input in the AD process. Data concerning digestate nitrogen content were collected on the field being primary data, while the nitrogen average content of the various inputs was collected in literature, as indicated by Table 5. Finally, the indicator presents the percentage of nitrogen recirculated through the AD process. In this case, 21% of the nitrogen contained in the digestate is recycled.

Table 5. N content per type of waste stream

Input	Value	Unit	N %	Reference
Cattle manure	3.20E+03	ton	2.66E+00	Shah *et al.*, 2014
Sewage sludge	2.00E+03	ton	4.70E+00	Leone *et al.*, 2021
Whey	7.10E+03	ton	1.40E-01	Wasserman, 1960
Wheat	1.10E+03	ton	4.00E-01	Paritosh *et al.*, 2017
Olive mill pomace	1.26E+04	ton	8.70E-01	Leone *et al.*, 2021
Agrumes pulp (fruit waste)	1.13E+04	ton	1.36E+00	Shah *et al.*, 2014
Chicken manure	2.57E+03	ton	1.95E+00	Hachicha *et al.*, 2009
Melasso (fruit waste)	2.10E+02	ton	1.36E+00	Paritosh *et al.*, 2017

LCA Results

LCA's characterization results, displayed per FU, are presented in Table 6. The most relevant emissions associated with the AD-CHP plant functioning are GWP, Human Toxicity, Acidification Potential, Photochemical Oxidation and Eutrophication Potential. Relevant emissions for the treatment plant are associated with an increase of GWP related to pollutants like methane biogen and nitrogen oxides. In particular, when biogas is lost, it releases methane biogen, negatively impacting the production yield of the biogas while generating greenhouse gas emissions. On the contrary, emissions impacting Marine Aquatic Ecotoxicity, Abiotic Depletion-fossil fuels, and CED relate to the electricity consumed by the treatment plant. The most relevant environmental impacts relate to the use of electricity, which comes from the Italian electricity mix, where the contribution of fossil fuels is considerable. The analysis includes the environmental credits linked to the avoided production and use of conventional mineral fertilizer and natural gas. This is common in LCA analysis since the activity considered entails the avoided production of conventional products (Salomone *et al.*, 2018). The analysis of the environmental credits associated with the avoided use and production of urea (the main component of mineral fertiliser) envisages relevant positive impacts for the overall system. The most relevant credits are connected to GWP, Marine Aquatic Ecotoxicity, and Human Toxicity. The credits associated with the avoided use of gas from conventional sources are Marine Aquatic Ecotoxicity, Abiotic Depletion and CED. Thus, most of the benefits associated with avoided products analysed concern reductions of non-renewable, fossil impacts. In conclusion, the environmental profile of the AD-CHP plant evidenced significant reduction compared to a linear scenario in which heat is produced from natural gas and digestate is replaced by mineral fertilizer. Thus, the strategy adopted by the cooperative in terms of the treatment plant is environmentally consistent.

Table 6. Characterization results per 1 MWh of electricity produced

Impact category	**Unit**	**Impacts**		**Credits**	
		AD-CHP	**Electricity**	**Mineral fertiliser**	**Heat from natural gas**
Abiotic depletion	kg Sb eq	-1.27E-04	0.00E+00	1.94E-08	-1.20E-04
Abiotic depletion (fossil fuels)	MJ	-1.34E+04	0.00E+00	1.37E+01	-8.16E+03
Ozone layer depletion	kg CFC-11 eq	-1.08E-04	0.00E+00	1.27E-07	-5.97E-05
Human toxicity	kg 1.4-DB eq	-4.36E+01	2.80E-01	6.23E-02	-2.05E+01
Fresh water aquatic ecotox.	kg 1.4-DB eq	-3.02E+00	0.00E+00	2.49E-03	-2.08E+00
Marine aquatic ecotoxicity	kg 1.4-DB eq	-1.58E+05	0.00E+00	3.41E+02	-2.96E+04
Terrestrial ecotoxicity	kg 1.4-DB eq	-2.69E-01	0.00E+00	4.20E-04	-1.11E-01
Photochemical oxidation	kg C_2H_4 eq	-3.27E-02	8.39E-02	1.93E-04	-4.39E-02
Acidification	kg SO_2 eq	-2.42E+00	1.17E-01	3.96E-03	-1.04E+00
Eutrophication	kg PO_4--- eq	-2.32E-01	3.04E-02	3.45E-04	-1.33E-01
Global warming (GWP100a)	kg CO_2 eq	-1.34E+04	0.00E+00	1.37E+01	-8.16E+03
Cumulative Energy Demand	MJ	-1.76E+04	0.00E+00	2.31E+01	-9.34E+03

Circularity Indicators and LCA: A Combined Approach

The LCA analysis assessed the environmental profile of the AD-CHP plant of Fattoria della Piana, evidencing the benefits associated with the avoided use and production of mineral fertilizer and heat from natural gas, as shown in Figure 2. Focusing on energy production, the main impacts are related to the presence of methane biogenic, which impacts in terms of GWP and Photochemical Oxidation. If the environmental profile of the treatment plant assessed through LCA and of the environmental benefits of the system is clear, more complex is the evaluation of its level of circularity. On the one hand, the strategy implemented by the cooperative closes the resource loop by producing bioenergy and recycling nutrients (Møller *et al.*, 2023); on the other, considering the so-called "butterfly diagram" provided by the Ellen McArthur Foundation (Ellen McArthur Foundation, 2019), AD is associated with a lower level of circularity. One of the core principles of CE is to maintain resources at their maximum value for as long as possible (Korhonen *et al.*, 2018), whether energy recovery does not imply further use of the materials, thus is limitedly circular. However, as reported in Table 7, KPI_1 allows us to enrich the evaluation by assessing the energetic valorisation capacity of the treatment plant in terms of organic waste, which is 43.99 m^3 CH_4 /ton of waste. On the same line, KPI_3 showed the treatment plant's selfsupporting capacity in terms of heat, evidencing almost the full coverage of heat requirements. Thus, the AD-CHP system showed an efficient production of energy, which is recovered through waste. Considering the recirculation of nutrients, the use of digestate and organic fertilizer evidenced an environmental credit towards the treatment system, with particular attention in terms of Marine Aquatic Ecotoxicity, Abiotic Depletion and CED. Moreover, digestate presents a valuable quantity of nitrogen, in particular of ammonium nitrogen, compared to untreated waste. Thus, KPI_4 evidenced that 21% of nitrogen present in the digestate is recycled or recirculated from the initial waste source. This confirms that the credit evidenced during the LCA analysis is related to the recycling of the nutrients contained in the waste. In conclusion, the present analysis, consisting of the combined use of LCA analysis and circularity indicators, generated mutually consistent and coherent results. LCA and CE indicators entail different but complementary perspectives. LCA identifies and quantifies the potential environmental burden occurring along the life cycle of a product. On the contrary, CE indicators monitor if and how much specific circular practices may increase the overall circularity of a given system (Samani, 2023). Thus, LCA does not directly assess the circularity of a system but can support decision-making and drive circularity implementation in companies (Pena *et al.*, 2021). Ultimately, to avoid the presence of rebound effects within the system a competing but complementary approach is needed (Leipold *et al.*, 2023). Moreover, the boundaries of the system analysed should be evaluated; the symbiotic exchanges occurring inside and outside the cooperative system with its partners in terms of waste allow for to reduction of the overall quantity of waste produced, nor change waste into resources, increasing the circularity of the system. This implies that the evaluation of a system in terms of circularity and sustainability may be affected by the choice of instruments and by the system boundaries adopted. This makes it crucial to conduct case-by-case evaluations. In conclusion, the introduction of circularity principles within its activities supports the company in reducing and reusing the waste produced and received; thus, the cooperative, reduces disposal costs, generates thermal energy for the company itself and creates additional income related to the production of electricity for the national grid, taking advantage by the incentive present at national level for electricity production.

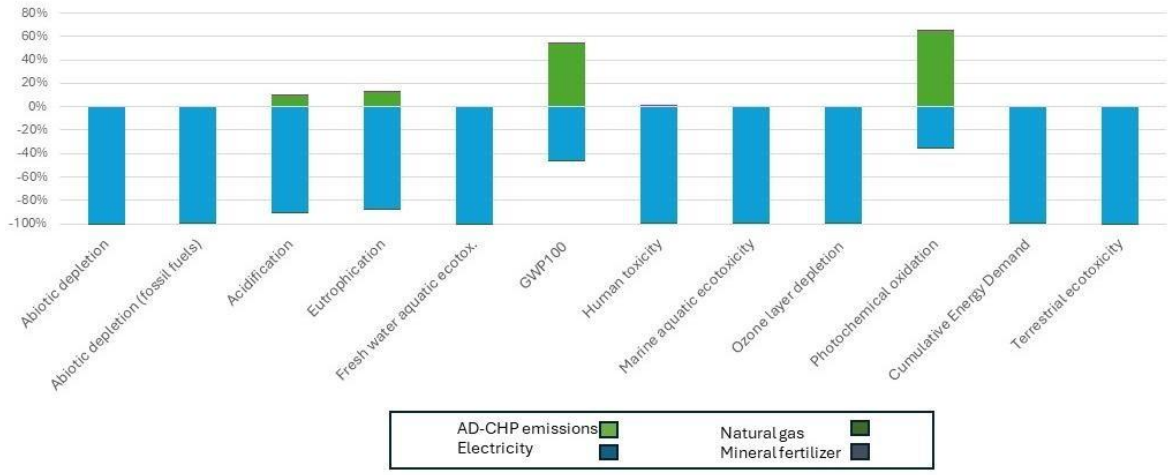

Figure 2. Characterization results per FU

Table 7. Overview of the KPIs measured

KPI$_1$	**KPI$_2$**	**KPI$_3$**	**KPI$_4$**
Biogas efficiency[a]	Energy balance[b]	Self-sustaining capacity[c]	Nitrogen recycling potential[d]
m^3 CH_4 /ton of waste	MJ/MJ	MWh	kg
4.40E+01	1.91E+00	9.75E+01 %	2.10E+01 %

[a] Higher values imply better performance. [b] Lower values imply better performance. [c] Higher values imply better performance. [d] Higher values imply better performance

Conclusion

The present preliminary analysis evidenced the environmental and circularity profile of the AD-CHP plant of the cooperative Fattoria della Piana by adopting a combined approach based on LCA and CE indicators. Circularity does not imply sustainability, so case-by-case evaluations are needed to ensure the sustainability of the circular strategies implemented. In this case, LCA and circularity analysis offered coherent outcomes. Despite being preliminary, the present study proposed an efficient approach that could guide companies of the sector towards circular and sustainable systems. LCA and circularity indicators outcomes are interpreted in a complementary way given that they provide different information, thus integration is not considered at this stage. In this preliminary study, the focus was on environmental sustainability, but CE embraces also economic and social sustainability. Thus, future developments of the study entail the monitoring and assessment of these two aspects Life Cycle Costing and Social-Life Cycle Assessment, completing the assessment with indicators targeted for the AFS. Moreover, future expansion of the study will evaluate all the supply chains of the cooperative. The current lack of unique metrics able to assess the circularity of the food system hampers circularity implementation at the company level and potentially generates greenwashing practices. Such a lack makes it challenging for food companies to include CE principles in their business. Finally, the ISO 59000 series is out, setting

definitions, values and metrics to assess circularity, however, the ISO is not sector-specific, thus the path is still long since challenges in tackling the specificities of the food sector remain.

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Implementing Extended Producer Responsibility (EPR) for Managing Post-Consumer Textile Waste in India

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Abstract

India, one of the largest textile-producing countries is challenged with the threat of producing 8,200 kilotons of textile waste of which 51% emanates from post-consumer textile waste. There is a surge in textile waste due to the influence of brands and ever-evolving fashion trends, which poses a threat to the environment by significantly increasing land pollution. Research studies indicate that there is a critical imbalance in treating post-consumer textile waste and a lack of awareness of disposal methods.

There is a need for a system-level intervention to tackle the post-consumer textile waste in India. This research proposes an implementation of the Extended Producer Responsibility (EPR) model suiting the Indian context. Inclusion of awareness along with this model emerges as a strategic intervention in textile circularity which offers sustainable and a long-term solution for the environmental repercussions of textile waste. An extensive literature study along with system blueprint and system thinking maps aided in developing a comprehensive understanding of textile waste management. From these insights, primary research was conducted to understand consumer behaviour on textile disposal. The research findings show that the brands have a considerable influence over the consumers' purchasing decisions. Consumers are also unaware of the disposal methods available.

Introduction

Recent years have seen emerging discussions around circular economy and sustainable development have been gaining popularity to reverse the years of environmental damage caused by industries all over the world. India is slowly trying to emerge as a global leader in promoting and implementing circular economy principles and practices to drive sustainable development and economic growth. Policies and committees have been reformed to relook at the current linear model of "Take-makedispose" and pivot into a more circular approach. Circularity refers to systematically devising a regenerative system that allows any product to circulate to its maximum value and continue to retain it by means of reusing or recycling, while simultaneously minimising the waste generated at every stage of production (Mohan *et al.*, 2022).

Many of the major industrial giants like Plastics, E-waste, and Petroleum and gas are in the process of adopting sustainable practices and policies to exercise the circular economy efficiently. The textile and apparel industry, being one of the largest contributors to the Indian economy has made a silent yet an impactful contribution to environmental harm over the years. This growing concern has been brought to highlight in the past decade. Years of unhealthy consumption of clothes and textile by the public under the influence of fast fashion without a supervision has resulted in this situation. The industry shows the promise of a growing need in circularity to managing its waste efficiently (Innovations *et al.*, 2023).

7793 kilo tons of global textile waste is accumulated in India every year primarily through three different streams, out of which post-consumer textile waste (PCTW) has a majority contribution of **51%**. This category of waste collects any piece of clothing or textile that is discarded by consumers. While the textile industry has not established a formalised waste management framework, it is regulated under the existing solid waste management framework. Apart from this, indigenous communities and local waste pickers have their own internal and informalized networks to manage it. Unfortunately, this still proves invaluable considering a staggering 43% of post-consumer textile waste (PCTW) gets landfilled or incinerated causing immense harm to the environment (Mohan *et al.*, 2022).

Post-consumer textile waste (PCTW) is often disposed of in garbage bins/dustbins due to the lack of categorisation and is subsequently sent to the local waste management centres. Without specific policies or rules guiding these centres on how to handle textile waste, it is typically sent to landfills or incineration facilities based on the condition of the clothing. Compounding the problem is the significant gap in a common person's knowledge on how to manage textile waste and its harmful effects on the environment.

Such a substantial gap in the management calls for a system level intervention which enables the textile waste management system to adhere to policies and practices and make the brands take responsibility for the lifecycle of their respective product. Currently, the textile waste management in India is integrated and regulated under the existing waste management framework for plastic management which can be a starting point to incorporate EPR. A separate EPR for textiles would allow separate resource allocation and would make the industry more accountable for their actions. It also opens possibilities to formalise the informal sectors, paving way for economic upliftment of communities (Dahiya, 2024).

This paper discusses developing a comprehensive and efficient circular waste management system for post-consumer textile waste in India through the implementation of Extended Producer Responsibility (EPR) policy with emphasis on informal sectors, paving a way for economic upliftment. While the overall research breaks down the multifaceted inefficiencies of the textile industry through a qualitative study, the current paper proposes environmental policies to catalyse the effective and circular management of post-consumer textile waste. The paper also advocates for a shift in the buying habits of the consumers through increased and repetitive awareness. It focuses on holding the stakeholders accountable for their product lifecycle and minimising waste generation. This approach looks for the solution "within the system" rather than "outside the system," thereby inherently making the approach circular**.** The subsequent section of the paper discusses the literature review, methodology, results, and conclusion.

Literature Review

Attributes such as sustainability, textile quality and effectiveness, and consciousness have led to ecomindful and eco-accommodating production for long-term benefits. Evaluating the existing waste management techniques for textile waste and consumption can lead to sustainable disposal of postconsumer textile waste (Ahmad, 2020). India is the second-largest producer and exporter of textiles in the world, making up 5% of worldwide trade. In the current generation, we cannot avoid material and waste production but consider alternative recycling technologies to be more sustainable. (Chand *et al.*, 2023) With such developments, waste material can be recognized as a resource.

Existing studies from the Journal of Material Cycles and Waste Management have reported that the amount of post-consumer textile waste is extreme amounts. This waste has been filling more than 14 million tons in the USA and the UK. Also, up to 75% of pre-consumer textile waste can be recycled while only 15% of post-consumer waste can be recycled. Due to minimum awareness, the life cycle of 73% of discarded clothes ends in landfills in India. With this rate, by 2050, India will require a bigger area as much as it is, to discard the waste it produces. Apart from landfill waste, it also leads to chemical pollution and water consumption, around 14kgs of water per person in 2021. It accounts for 10% of global pollution and 8% of CO2 emissions. The paper, "Textile and apparel industries waste and its sustainable management approaches," highlights the major contributors of textile waste and its impacts and gives insights on how to combat textile waste and reduce its environmental impacts through the approaches of reduce, reuse, and recycling. (Chand *et al.*, 2023)

Talking about the processes and methods of waste management, "Emerging trends in informal sector recycling in developing and transition countries," states that only 30% of waste generated in developing countries is sent for disposal whereas the rest of the uncollected waste is disposed into open dumps. This waste is often collected by waste pickers, also known as scavengers, who consider waste as a resource for income generation. They collect a variety of indigenous materials out of which textiles are one such material. (Asim *et al.*, 2012) This community barters old clothes in exchange for utensils or money. They later sell this to aggregators or other second-hand clothing stores. They follow the process of segregating, washing, and ironing clothes which are later sold to retail or wholesale shops. Informal Sector Recycling (ISR) promotes benefits such as economic growth, litter control, and conservation of resources. They extract recyclable materials from municipal solid waste and are usually exempted from state agencies. (Ezeah *et al.*, 2013)

In India, though there is less reliable data, it is estimated that there are almost six million informal waste pickers. ISR is not yet a part of the government's waste management policy but there are partnerships involving communities and public and private sectors. Recycling provides employment opportunities and a way of livelihood for impoverished and underprivileged social groups (Damghani *et al.*, 2008) The activity of recycling provides a reliable supply of second-hand raw materials which eliminates the production and importation of new materials. The paper speaks about integrating this informal sector into formal municipal solid waste management to be more sustainable and productive. This can be achieved by developing a strong framework that would benefit both sectors socially, environmentally, and economically. The structure developed must consider the local context and conditions instead of developing a universal model. (Ezeah *et al.*, 2013)

Regarding the waste management methods of post-consumer textile waste, the study done by Dahiya, "Roadmap to Sustainable Textiles," gives insights into the possible measures that might help in protecting the environment from the harmful effects of textile waste. It explores the idea of channelling textile waste into recycling infrastructure during the production process. It talks about extended producer responsibility (EPR) and whether it can help accelerate the circular economy. It also explores if increased social awareness of resource conservation methods and waste reduction techniques can promote conscious consumerism and sustainable consumption. The paper states that policies related to EPR would give a boost to modern technologies in the production stage. For sustainable textile waste management, a sophisticated approach is required that involves multiple stakeholders including the informal textile

sector. Currently, only France has a law on textile waste management (Bowers, 2019). In India, the existing waste management framework is integrated under plastic waste management. The author concludes by saying that having a separate EPR on textiles would make the industry more accountable and responsible, and making the consumers aware would lead to a step towards conscious consumption. (Dahiya, 2024)
"The role of Extended Producer Responsibility (EPR) in reducing textile waste, Textile Focus," states that managing textile waste is a complicated process and therefore requires multiple strategies and policies to combat textile waste on a larger scale. More importantly, dealing with post-consumer waste is usually inefficient due to informal trading within the community. To deal with this proper policy measures are required such as EPR. Textile waste not only consumes landfill waste but also results in a loss of half a trillion dollars annually. EPR is a policy that extends a producer's responsibility for their product to the post-consumer stage. It is a way of awarding responsibility for the product to its producer. This responsibility travels from the manufacturing stage to either recycling or landfilling. It helps in shifting the responsibility from the consumer to the producer and helps the producer consider the environmental impacts of their product. It helps in promoting the development of recycling technologies and the process of diversion of textile waste. Successful implementation of EPR in France has impacted improving recycling rates and reducing landfills. This is by mandating the producers to collect half of what they introduced in the market. EPR has its challenges such as financial feasibility and development of technology. Intervening in these aspects and re-educating the consumers will provide EPR as a catalyst and give place to other such policies. (Akter, 2024)

The paper "Death by waste: Fashion and textile circular economy case" talks about the importance of a circular economy and the need for it in the textile sector. Increased population rate has led to the faster generation of clothes resulting in two-thirds of non-biodegradable, synthetic fibres. To avoid the decreased life cycle of textiles, the circular economy is a step towards a sustainable solution. This not only reduces solid waste in landfills but also reduces the production of new materials. According to the Paris Agreement, the initial target is to reduce greenhouse gas emissions by at least 30%. This can be achieved by targeting the pre-production stage, through the ideology of circular economy. Various research papers, case studies, and data from the Australia Bureau of Statistics gave insights into the environmental impact of textile waste. From this data, it is evident that implementation of the new ideologies and policies, related to circular economy and recycling, will reduce the amount of water and chemical pollution. Along with recycling, the circular economy includes reducing, repurposing, reusing, and repairing. Recycled textiles have been used in the construction and industry sectors, paper industry, automobile industry, agriculture industry, and furniture industry to name a fewm (Shirvanimoghaddam *et al.*,2020)

The paper "Addressing post-consumer textile waste in developing economies" highlights postconsumer textile waste, consumer attitudes, and disposal behaviour. A systematic approach is required to tackle PCTW which includes an understanding of consumer behaviour, waste management practices, and policies. In developing countries, textile waste has taken up at least 6% of total landfills, which is segregated into non-hazardous and inorganic due to which it is considered unusable. This waste is sent to either landfill or incineration, lacking in the circular economy. Sinha explores consumer disposal behaviour and identifies the issues as awareness, fashion value, textile durability, disposal route, and environmental attitudes. A case study was developed in two phases to conduct this study. The first phase consists of semi-structured interviews with stakeholders while the second phase includes a consumer survey. The

qualitative and quantitative data that was collected in the survey were collected according to consumer attitudes towards textile waste, awareness, responsibility, positive contribution in disposing of textile waste, and disposal habits. A limited number of the population is aware of the harmful environmental effects which led to inactive participation in safer disposal. This survey has concluded that education programs and business opportunities must be developed along with appropriate policy initiatives to tackle textile waste (Sinha *et al.*, 2022).

Methodology

To gain a holistic understanding of the current textile waste management industry, a detailed qualitative research methodology was employed. This methodology includes an in-depth literature study to acquire secondary data, semi-structured interviews with industry experts followed by a survey to understand consumers' point of view and system thinking maps to synthesise the data for further direction. Literature studies were focused on understanding the current dry waste management system and how it gets collected, sorted, and treated. Additionally, the studies also explored consumer buying habits and their relationship to post-consumer textile waste.

Semi-structured interviews were conducted with industry experts with 7 people from various stakeholders of the textile industry, including recyclers, entrepreneurs, dry waste management centres, tailoring shops, and fashion merchandisers. The interviews were conducted with pre-determined questions focusing on current recycling practices, challenges faced by the industry, consumer behaviour and policies adopted by foreign countries. The interview questions were contextual which covered the different mindsets of the different stakeholders involved, providing a deeper understanding of the existing textile waste management system.

Quantitative data was collected through a survey to understand the consumer mindset on postconsumer textile waste and their awareness of disposal methods. The total number of respondents was 55. The sample targeted urban residents of different ages and demographics to understand their current and desired actions. The respondents' ages vary from 19 to 61. The questions in the survey were developed based on the literature review and interviews. The questions were framed in a way to understand behavioural patterns, awareness levels, attitudes, opinions, and potential motivators related to the management and disposal of post-consumer textile waste.

System thinking maps were used to synthesise and visualise the complex relationship and feedback loops within the textile waste ecosystem. Iceberg mapping was used to understand the events, patterns, infrastructure, and mental models contributing to the increase in post-consumer textile waste. Interconnected circle maps were used to reveal the relationships and interconnections of each element. A causal-feedback loop diagram helped in visualising the cause-and-effect relationship among the elements with more connections.

Results and Discussion

The findings from the qualitative and quantitative data have produced insights on the current stance of post-consumer textile waste.

Insights from Interviews

Insights from entrepreneurs

Textile waste is predicted to be a crisis within a decade due to overconsumption and lack of infrastructure to treat it. Most of the landfills have 80% of the soiled clothes. It is possible to treat and recycle any cloth by having the right knowledge and infrastructure. In India it is estimated that there are 7 to 8 textile recovery factories. Seasonal pick-ups are arranged throughout the year to collect clothes from the consumers. Consumers usually contact them to pick up their clothes through various channels, such as Instagram, WhatsApp, phone, website, and email. This makes it feasible for the consumer to dispose of their textile waste. After collecting, they are taken to the factory and thoroughly analysed the textile composition by the specialist. They are segregated based on the fabric type and the cloth's condition. If in good condition, it is sent for upcycling to skilled people who convert the waste into a usable product. The clothes that are in bad condition are sent for recycling. Here, every yarn is separated from the cloth by the experts and is sent to make recycled yarns. The interviewee also pointed out that consumers are reluctant to use recycled products, assuming that the quality is bad. Although there is a lot of awareness on spreading sustainable practices, consumers still need help to dispose of clothing properly.

Another interview was conducted with an entrepreneur who collects post-consumer textile waste via an app which facilitates the consumer to schedule a pick-up and declutter their wardrobe. India has many manufactured textile dumps that are increasing land pollution. The app enables the consumer to schedule pick-up to the consumer's place, and a representative collects them. It is transported to the warehouses and is segregated into distinct categories by analysing the textile components (cotton, nylon, polyester, etc). The data and analysis are recorded in the CRM, which helps in understanding how much is stocked in their warehouse. Clothes that are in good condition are either upcycled, refurbished, or sent back to the market. If not in good condition, they are sent to recycling facilities, which convert the cloth into fresh yarn and bring it back to the markets by making it circular. A cash-back system is enabled after the fabric has been collected from the consumer and put into the app's wallet, which is an incentive to encourage consumers to be a part of sustainable living. The interviewee also gave us some consumer patterns and living towards post-consumer textile waste. Due to fast fashion, there are a lot of clothes in the wardrobe. Consumers can afford it and end up buying impulsively. In a household scenario, the cloth is given to the domestic workers or if they are torn, it is used as a wiping or dusting cloth. As the dust keeps accumulating in the fabric, it gets dirty, which prompts them to throw it into the dustbin, leading its way to the landfill. There is also another assumption that there is no return value while purchasing clothes. Consumers, at times, do not declutter because they feel they will not get any value. Through this, the consumer is still trying to protect the environment by not throwing it in the landfill and stopping the carbon dioxide emissions. They buy expensive clothes for Rs.4000 and stop using them after 6 months. Due to the cost, they tend not to want to give it to others, giving it for recycling due to less incentive (around Rs.60) or throwing it away. Hence, such clothes are sent to thrift shops where they get a decent amount in return for the money they have paid. It has also been noticed that there is still a lack of understanding of consumers' responsibility to the environment. Awareness is needed, and it is expected to evolve slowly. Producers have started to initiate bringing the textile waste back to the economy by mixing virgin fibres with the recycled fibres to create new garments. Recycled fibres' bonds are less durable. Hence, there is a need to combine them with virgin fibres. Recyclers must find their way to channelise to bring back these recycled fibres back to the market.

Another entrepreneur emphasised their views on the financial side of recycling which is an expensive process and requires more capital investment. Making it a profitable business is hard, and it must be done eventually. The textile waste is hard to recycle due to its unique compositions and structures. Although recycling and upcycling are sustainable ways of generating textile waste, they also come with huge costs. To collect the textile waste, rag pickers go door to door of the houses and collect them. After collection, they bring it to the aggregators, who pay them in return.

Insights from fashion merchandiser

One of the interviews was with a fashion merchandiser to understand how fashion houses dispose of their textile waste. The fabrics are sourced from the wholesaler, and the merchandiser analyses them. After selecting they are printed with a design pattern and are sent for garment construction. During this phase, a lot of textile waste is produced by cutting and stitching. They are all collected as a bundle, and it is sent to aggregators or 'chindiwallas.' They bring the clothes to the warehouses and distribute the clothes to various organisations and start-ups depending on their requirement.

4.1.3. Insights from Tailor

Interviews with tailors were conducted to understand their way of managing the textile scraps. If there is enough fabric left, they are used for making pockets, creating patchwork, and making dresses for the deity idols. When there are small pieces, they are packed in plastic bags, and they are cleared whenever the garbage van comes and collects.

Insights from waste management centres

Interviews were conducted with a representative from the dry waste management centre to understand how government and municipal corporations deal with textile waste. The dry waste management centres receive more textile waste from their everyday household waste collection. Most of the dumped clothes are torn, substandard quality, or soiled. The clothes that could be reused are taken by manual segregation. Since they do not know the composition of each cloth, it is hard for them to segregate. Hence, they are collected and are sent to landfills. From there, it is sent to incineration plants.

Interviews were also conducted with waste mart. Textile waste is not usually collected as there is no proper channel or infrastructure to recycle it. In contrast, paper, plastics and electronic wastes have recycling centres that they are linked with. If any textile waste is collected, if it is in good condition, they take it, and if not, they are dumped into the garbage vans. The major reason for not collecting textile waste is that there is no return or enough money paid to the waste mart workers.

Insights from Consumers

A questionnaire was distributed to participants living in urban areas to understand how they deal with post-consumer textile waste. 55 responses were recorded. 30.9% of the respondents clear their clothes from the wardrobe once a year. 25.5% of the respondents dispose of their clothes rarely. 18.2% clear their clothes when they do not have much space in their closet. The respondents' actions were recorded to understand use cases for dealing with post-consumer textile waste. 45 of them donate the clothing for someone in need or give it to their house help. 40 respondents recorded that they would repurpose the

clothing as wiping cloth or for other household activities. 31 respondents would pass it on to their family members. 7 of them recorded that they would throw their clothing away. 60% of the respondents are not aware of what happens to the clothes when they give it to someone else or are thrown away. 38 out of 55 respondents think of recycling or repurposing their clothes in a usable way, whereas 14 out of 55 of them might or might not go with the above techniques. To understand what would motivate the respondents to give another life to their clothing, 39 respondents would like to know that their clothing is managed in a sustainable way, which provides them with a good feeling that they have helped the environment. 34 respondents prefer to be educated on how to repurpose the clothing. 33 of them would like to find feasible methods to send their clothing to some facility which deals with post-consumer textile waste.

System Thinking Maps

One of the most prominent issues emerging from the study was that the consumers are not aware of disposing methods, dumping the waste in the landfills and there is lack of awareness about the recycling facilities. To understand the systemic causes of post-consumer textile waste, system thinking maps were used to identify the key elements in the ecosystem holistically and identify from where it all stems from.

Iceberg model

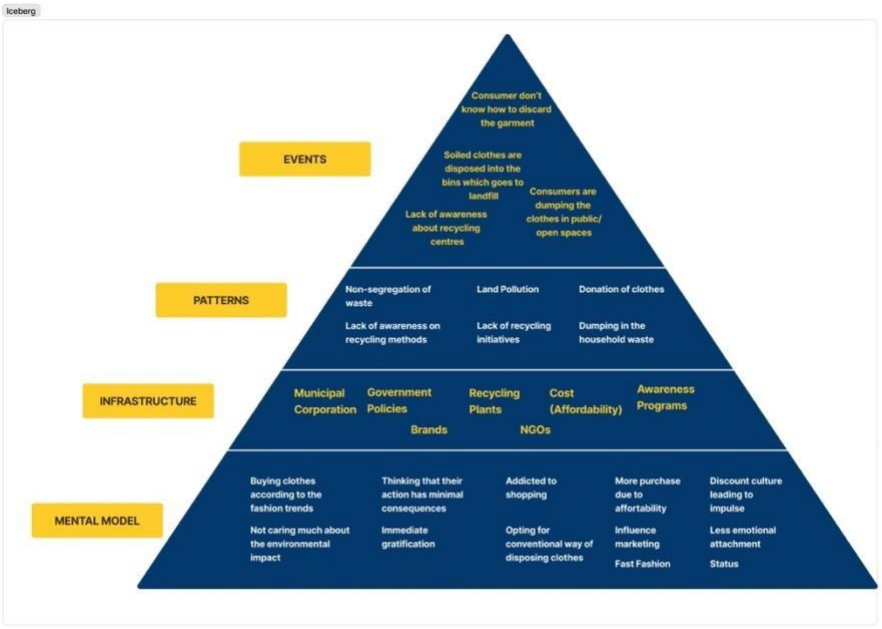

Figure 1. Iceberg Model Map

Applying the iceberg map has helped the study to zoom out and give a unique perspective on postconsumer textile waste. This has helped to view the ecosystem not just at the problem level but also at various elements that contribute to the ecosystem. Each level in the iceberg map enables thinking on elements or factors for the problem. The event level defines what issue is seen in post-consumer textile waste. The events that are seen on the surface are as follows: 1. Consumers do not know how to discard their clothes 2. Soiled clothes are disposed of in the bins and go to landfills 3. Lack of awareness about

recycling centres, and 4. Consumers are dumping clothes in public or open spaces. The next level to identify is the patterns that increase post-consumer textile waste. Patterns identified are land pollution, donation of clothes, lack of awareness of recycling methods, non-segregation of waste, lack of recycling initiatives and dumping in household waste. After patterns come the infrastructure that revolves around the ecosystem, such as municipal corporations, government policies, brands, recycling plants, cost (affordability), NGOs and awareness programs. The last level to identify is the mental models. This questions the area from which the problem stems. The mental models identified are as follows - buying clothes according to the fashion trends, not caring much about the environment, thinking that the consumers' action has minimal consequences, immediate gratification, being addicted to shopping, opting for the conventional way of disposing of clothes, more purchasing due to affordability, influence marketing, fast fashion, discount culture leading to impulse purchase, less emotional attachment and status.

Interconnected circle

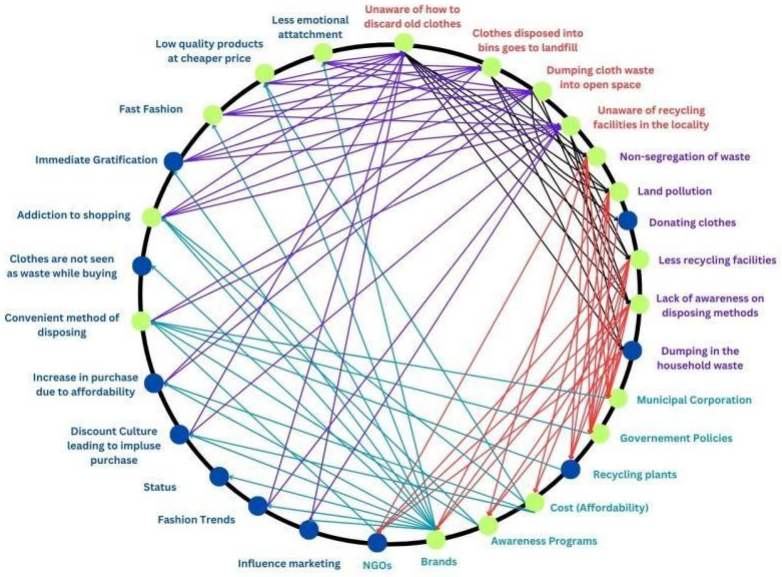

Figure 2. Interconnected Circle Map

The elements identified in the system thinking map are then placed on a circular loop. The interdependencies and relationships of the elements in the interconnected circle are mapped in the following structure - Events and Patterns, Patterns and Infrastructure, Infrastructure and Mental Models, and Mental Models and Patterns. One of the major interconnections is seen with the brands and much of the mental model. From the interconnected circle, brands influence and encourage fashion trends, influence marketing, enable status, discount culture leading to impulse purchase, increase in purchase due to affordability, clothes are not seen as waste while buying, addiction to shopping, immediate gratification, fast fashion, low-quality products at lower prices and less emotional attachment. The convenient method of disposing in the mental model sections shows responsible infrastructures like

municipal corporations, government policies, recycling plants, awareness programs and NGOs. Mental models such as immediate gratification, fast fashion, lower quality products at cheaper prices and less emotional attachment create a threat to the environment and affect all the elements at the event level. 'Unaware of how to discard old clothes' shows its cause-and-effect relationship in the patterns such as non-segregation of the waste, land pollution, donating clothes, less recycling facilities, lack of awareness of disposal methods and dumping in household waste. Government policies and municipal corporations in the infrastructure sections show their interdependencies with all elements in the patterns section.

Causal feedback loop

The causal feedback loop emphasises how each element can change dynamic effects in post-consumer textile waste. The strong connections that were found in the interconnected circle are used in the causa feedback loop map. All the elements on the map end up in land pollution. Loops mostly emerge from brands that create an increase in fast fashion, leading to less emotional attachment. Due to this, clothes are disposed of as the trends keep changing, which finds its way to landfill and causes land pollution. A lack of government policies leads to less awareness programs on post-consumer textile waste. There is a lack of awareness of disposal methods for post-consumer textile waste, which causes the consumer to dispose of their clothing along with household waste, which finds its way to landfills and creates land pollution.

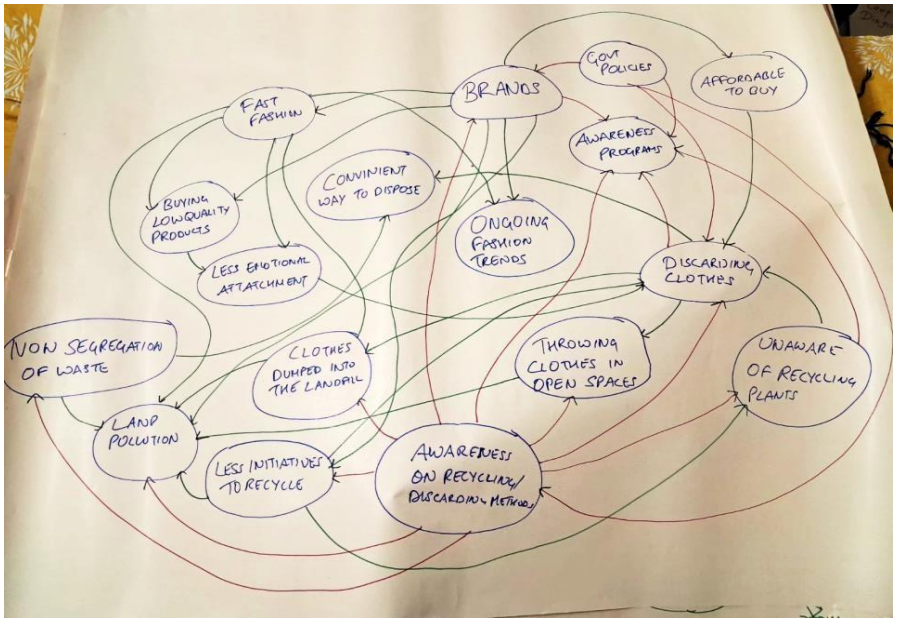

Figure 3. Causal Feedback Loop Map

Environmental Policy and Awareness

Extended Producer Responsibility is an extended responsibility of the producer to handle the entire life cycle of the garment including collecting and recycling of their garments. EPR was established in the formation of Producers Responsibility Organisation (PROs) who overlooks EPR in general. The policy encourages brands to use responsible and sustainable practices in manufacturing their clothes and collect clothes back which is then brought back to the economy and maintains circularity. Implementing EPR in

India could aid in managing post-consumer textile waste in India. It also increases employment opportunities for various people such as fabric experts, tailors, artisans, self-help groups, sorters, segregators, and recyclers. The policy can also streamline the process of collecting textile waste from the consumer as it establishes proper channels for the consumer to declutter their wardrobes. Strategies like providing incentives for the customers can boost the increase in collection. A proper statistical report from the brands regarding their process of using textile waste can create a sense of feeling good in the consumers as they subconsciously feel they had done well for the environment.

Adopting sustainable practices of reuse in India has been there for ages but due to overconsumption of clothes there is still a need for awareness on how to dispose of clothes the right way. Brands can take the responsibility and create awareness on disposing methods and consequences of post-consumer textile waste. Since brands hold a power on a consumers' buying decision, imparting sustainable practices through repetitive campaigns fosters the idea of sustainable living. This can improve the brand's image and loyalty towards consciousness.

Conclusion

India, being one of the major players in mechanical recycling, faces significant challenges in adopting efficient and eco-friendly ways to tackle post-consumer textile waste (PCTW). This research has highlighted the various inefficiencies in the current textile waste management system and gaps in consumer knowledge which stand responsible for the sloppy management of PCTW. The linear approach of the textile waste management proves ineffective in managing the disposal of PCTW. The issue becomes particularly concerning when we encounter large statistics indicating that Post consumer textile waste (PCTW) has the highest environmental impact. This is primarily due to the lack of proper disposal methods and recycling policies that could pivot the consumers towards a clean and circular approach in managing PCTW. Poor disposal practices result in textile waste rotting in landfills and incineration centres, causing increased CO_2 levels, land, and water pollution among other environmental harms. Our analysis of the current waste management system combined with insights into consumer behaviour underscores the pressing need for systematic interventions.

This study identifies no circular policies pertaining to post-consumer textile waste. Clothes are disposed of in dustbins, carried to landfills, and later incinerated, which is hazardous to the environment. One of the major concerns is that there is a lack of information about the composition of the clothes; hence they are sent directly to the landfills and incineration plants. Bringing in a circular approach could help streamline the post-consumer textile waste. Through system thinking maps, it is identified that brands have a huge influence on the mindset of consumers' buying patterns. There is also a lack of policies and clear instructions from the government on tackling post-consumer textile waste in a circular approach. Consumers are also unaware of recycling facilities available in their locality, which leads to dumping the clothes in the dustbins. There is limited knowledge among consumers on the repercussions of textile waste, leading to choosing a convenient way of disposing of their clothing.

To monitor the brands' influence in India, implementing EPR as a policy would make brands responsible for the entire lifecycle of their product, including design and production to disposal recycling. Running repetitive awareness campaigns by the brands could educate the consumers regarding the policies, which

would help them make informed decisions. To conduct educational campaigns to inform consumers about the environmental impact of textile waste, the importance of sustainable fashion choices and how to upcycle their garments. Educating the brands about the circular economy and how that could be executed in their business through workshops and sharing existing case studies of successful implementation by other brands. Supporting the development of a market for recycled materials and products to ensure economic viability. Encouraging partnerships between the government, brands, and non-profits to drive EPR and circular economy initiatives.

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Waste and By-Products of Olive Oil Supply Chain: A Systematic Review of Treatment Technologies and Eco-Efficiency Assessment Tools.

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Abstract

The olive oil supply chain generates a notable amount of waste and by-products that, if not properly managed, can cause several significant environmental impacts. On the other hand, they constitute a great source of high-added value compounds, although, the efficiency in the recovery of these compounds depends on the technologies used. To the authors' knowledge, eco-efficiency indices and approaches are less considered in the olive oil sector and, in particular, in olive oil waste treatment and valorisation technologies, than in the agribusiness sector in general. For this reason, the present study provides a systematic literature review to analyse the state-of-the-art waste and by-product treatment technologies in the olive oil production processes, focusing on their valorisation strategies and the evaluation of their eco-efficiency approaches and tools, considering environmental sustainability and circular economy point of view. The findings identify the main treatment technologies adopted and their valorisation pathway in a circular economy strategy, exploring the eco-efficiency of these technologies in the olive oil supply chain, in a circular economy and environmental sustainability context. Therefore, this work can contribute to achieving SDGs 9 and 12.

Introduction

Olive oil production is one of the most important activities in the agri-food sector, especially in Mediterranean countries, with an important socio-economic and cultural relevance. Global olive oil production in 2023 reached 2.73 million tonnes. Spain is the leading olive oil producer (28.6%), followed by Greece (12.8%), and Italy (8.6%). The global olive oil consumption amounts to 3.1 million tonnes (International Olive Oil Council, “olive oil distribution-2023”). Spanish exports of olive oil reached 1,068,029 tonnes in the 2021/2022 crop year (from October to March) for an estimated value of €3.9 billion, placing it in first place followed by Italy with 357,832 tonnes and €1.7 billion; Portugal with 253,735 tonnes and €893.7 million; and Greece with 137.180 tonnes and €571.9 million (International Olive Oil Council, “Export figures of olive oil in the European Union (EU-27)-2022/2023 crop year, 2023).

Olive oil is obtained by processes involving several steps, i.e., olive fruit washing (defoliation and olive washing), crushing, and malaxation to break into the emulsion, and then oil separation and extraction (Shabir *et al.*, 2023). Procedures of olive oil extraction and separation have improved over time, due to economic factors, environmental concerns, technological advancement (Gebreyohannes *et al.*, 2016), the increasing demand for olive oil worldwide over the past decades (Ochando-Pulido *et al.*, 2015), as well as the shift from agricultural to industrial settings. In particular, the cultivation and harvesting phase and the physical processing of olive and olive oil extraction technology have undergone many changes over the years, affecting the various waste and by-production quality and quantity production and management.

In this regard, during olive processing, three main types of by-product/waste are generated, i.e., olive pomace, solid mill wastes (olive pits, kernel, and leaves), and olive mill wastewaters (OMWWs) (Dahdouh *et al.*, 2023). The improper management of olive oil waste and byproducts on soil may cause a strong phytotoxic effect, may increase soil hydrophobicity, decrease water retention, and affect the soil acidity, salinity, N immobilization, microbial, nutrient leaching, and organic acids. In particular, the high polluting activity of OMWWs is due to the high content of organic molecules, especially polyphenolic mixtures (1-10 g/L) with different molecular weights, which are responsible for toxicity in seed germination (Dehmani *et al.*, 2023), aquatic organisms (Fiorentino *et al.*, 2003), and bacteria (Mekki *et al.*, 2006). Despite the toxicity of these by-products and waste, many studies (Carluccio *et al.*, 2003; Dini *et al.*, 2020; Nunes *et al.*, 2022) highlight the beneficial, antiinflammatory, and antioxidant properties of the polyphenols compounds contained in olive oil, even though the composition of the product can change depending on several external factors (cultivars, growing conditions, and extraction processes). Therefore, the properties of the polyphenolic and phenolic compounds contained in these wastes and by-products make their recovery attractive for uses in various fields, such as pharmaceutical and therapeutic uses (Sicari *et al.*, 2023), to increase food quality (Pampuri *et al.*, 2021; Sar *et al.*, 2020) or to produce bioplastics useful for food preservation and packaging. Many studies in the literature have also highlighted other possible ways for valorising this olive oil wastes and by-products in a circular economy perspective, also representing an important source of economic incentives and earnings for companies (Donner *et al.*, 2022; Valta *et al.*, 2015). Therefore, the valorisation of olive oil wastes and by-products as raw materials may promote the sustainability and circularity of the sector by helping to reduce environmental impact and production costs (Valta *et al.*, 2015). Despite this, the main problem regarding the treatment of olive oil wastes and by-products is related to the identification of environmentally and economically friendly solutions (Roig *et al.*, 2006). In this contest, the eco-efficiency assessment for treatment technologies and valorisation strategies for olive oil wastes and by-products could be useful for achieving more eco-sustainable management and help mill companies to shift from a linear to a circular supply chain perspective. The eco-efficiency concept is relatively recent, and it was popularised by the World Business Council for Sustainable Development (WBCSD) (WBCSD, 1996; WBCSD and United Nations Environment Programme, 1998) underlying the idea that by creating "more value with less impact" can move the companies and the society towards more sustainable use of resources (WBCSD, 2000). Increased integration of eco-efficiency and its evaluation in this area allows for improved treatment efficiency with suitable outputs of other useful raw materials, facilitating a return of resources and minimizing the environmental impacts associated with these systems. In this regard, this study aims to conduct a systematic literature review in order to define the state of the art of treatment techniques and valorisation for olive oil waste and by-products, exploring also their eco-efficiency assessment in a circular economy and environmental sustainability point of view. The analysis was performed focusing on two main research questions: i) 'what is the state of the art of treatment technologies used for olive oil production by-products and wastes aimed at their valorisation?'; and ii) 'how many of these technologies do the literature associate the concept of eco-efficiency?'. Through this analysis, it is possible to obtain a more comprehensive and integrated approach to improving the best available treatment technologies and valorisation for olive oil wastes and by-products to safeguard water and land ecosystems, achieving a zero-waste system and zero-emissions production.

Literature Review

Many studies have focused attention on ways of reuse and valorisation, highlighting how the value contained in these olive oil wastes and by-products do not lie only in the recovery of polyphenolic substances, but also in other valorisation fields of interest, such as compost and fertilizer production (Alburquerque *et al.*, 2006; Galliou *et al.*, 2018), energy recovery (Akgul *et al.*, 2021), for the production of add value compounds (Padilla-Rascón *et al.*, 2020) and biosorbent material (Esteves *et al.*, 2022).

Many authors consider olive oil waste and by-product valorisation as strategies to implement circularity and environmental sustainability in the treatment systems (Cifuentes-Cabezas *et al.*, 2022; Esteves *et al.*, 2022). Many authors have focused on improving the efficiency of olive oil wastes and by-product treatment technologies in the literature. Other studies have mainly aimed at searching for the best material valorisation strategies, from a circular economy perspective, or have focused on implementing eco-sustainable management practices for waste and by-products. However, to the authors' knowledge, no studies focus on providing a mapping of all treatment technologies for olive wastes and by-products considering their valorisation and assessing the eco-efficiency of the technologies employed, also from an environmental sustainability and circular economy perspective. The paradigm of circular economy is the keystone resource-oriented model of economic production and consumption that puts forward environmental sustainability (Sauvé *et al.*, 2016; Stempfle *et al.*, 2021). However, it is important to highlight that the circular economy is not always synonymous with environmental sustainability (Kounani *et al.*, 2023). In this regard, a potential solution to achieve efficient treatment technologies by also including circularity and environmental sustainability assessment is eco-efficiency. Although in literature there is no common definition of eco-efficiency, Koskela and Vehmas (2012, p.547-548) define it as a solution for producing high-quality products using less natural resources and reducing the environmental impacts, thus considering the statement “more from less” (Koskela and Vehmas, 2012), and focusing on productivity (i.e., producing more value-added with less environmental impacts) or intensity (i.e., decreasing the environmental intensity of the economic performance). However, the main aspect is that eco-efficiency may be considered as a ratio between the reduction of environmental impacts and the increment of the value of production (Huppes and Ishikawa, 2005). Hence, ecoefficiency combines the efficiency of treatment and valorisation of olive oil wastes and by-products, intending to reduce environmental impacts. Hence, while the circular economy provides avenues for reducing olive oil wastes and by-products and increasing its valorisation (Kounani *et al.*, 2023), the ecoefficiency tools help to measure how much those circularity strategies are also environmentally sustainable. Thus, this systematic literature review aims to analyse the state-of-the-art waste and byproduct treatment technologies in the olive oil production processes, focusing on their valorisation strategies and the evaluation of their eco-efficiency approaches along with or without an environmental sustainability and circular economy point of view.

Methodology

The systematic literature review is a rigorous and transparent method for identifying, evaluating, and synthesizing useful information about literature article samples that address a specific research question

or hypothesis (Mengist *et al.*, 2020). It aims to minimize bias and provide a comprehensive summary of relevant findings (Snyder, 2019). To ensure the coherence, robustness, and replicability of the research method considered in this analysis, the Preferred Reporting Items for Systematic Review and MetaAnalysis (PRISMA) statement is selected as the formal guideline (Page *et al.*, 2021).

The method is schematized in figure 1 and starts by defining two research queries with the following keywords: the first query (query 1) was structured as follows: ("olive oil") AND ("by*product*" OR "olive mill" OR "mill waste*") AND ("treatment technology*" OR "waste* treatment*"); while the second query (query 2) was defined as follows: ("olive oil") AND ("by*product*" OR "olive mill" OR "mill waste*") AND ("eco*efficienc*" OR "environmental impact*" OR "resource management" OR "environmental sustainability"). The choice to run two different queries arises from the need to collect a consistent and specific sample of studies to answer the research questions. Indeed, query 1 mainly focuses on olive oil waste and by-product processing technologies and related valorisations, while query 2 is principally focused on the eco-efficiency assessment, the circular economy approach, and the ecosustainability of these processes. Both queries are run on the Scopus and Web of Sciences (WoS) databases to search for high-quality international scientific articles. The research is conducted without defining any specific time frame and it is updated to December 2023. Initially, the result of the research showed n=575 for query 1 and n=176 for query 2. Before the screening phase, all those papers that are neither reviews nor articles**,** nor in English, and all duplicates are removed from these initial samples. The screening phase includes a selection of papers coherent with specific eligibility criteria, and includes, for both queries, only studies that focus on olive oil waste and by-product treatment technologies along with valorisation pathways. In this way, it is possible to highlight in query 1 the state-of-the-art treatment and valorisation technologies for olive oil waste and by-products, while in query 2 to investigate how the eco-efficiency is considered in the study of these treatment technologies, considering the eco-sustainability and circular economy principles. Since the eco-efficiency standard definition is lacking in the literature, to better understand and clarify this selection, eco-efficiency was distinguished into two approaches:

A theoretical eco-efficiency approach that is based on the relationship between high treatment efficiency and low environmental impact associated with that treatment, according to Huppes & Ishikawa (2005, p.641-642), but without specifying an indicator to measure its eco-efficiency performance; an integrated approach to efficiency that considers specific methods or indicators for assessing eco-efficiency, according to Rybaczewska-Błażejowska and Gierulski, (2018, p.2), although they are not considered as such way in the study considered (Rybaczewska-Błażejowska and Gierulski, 2018).

At the end of the screening phase, 208 articles and 14 reviews are included in the final sample for query 1 and 41 articles and 13 reviews are included in that one for query 2. Microsoft Excel software is used for collecting data and gathering systematically the information contained in both queries. In query 1, data analysis is carried out considering the contest of analysis, thus focusing on the type of olive oil waste, the investigated treatment technologies, and the valorisation pathways. Meanwhile, in query 2 data analysis is realized considering if there are eco-efficiency theoretical or integrated approaches, and collecting also information about circularity strategies and environmental sustainability approaches and if they are considered together with eco-efficiency or not.

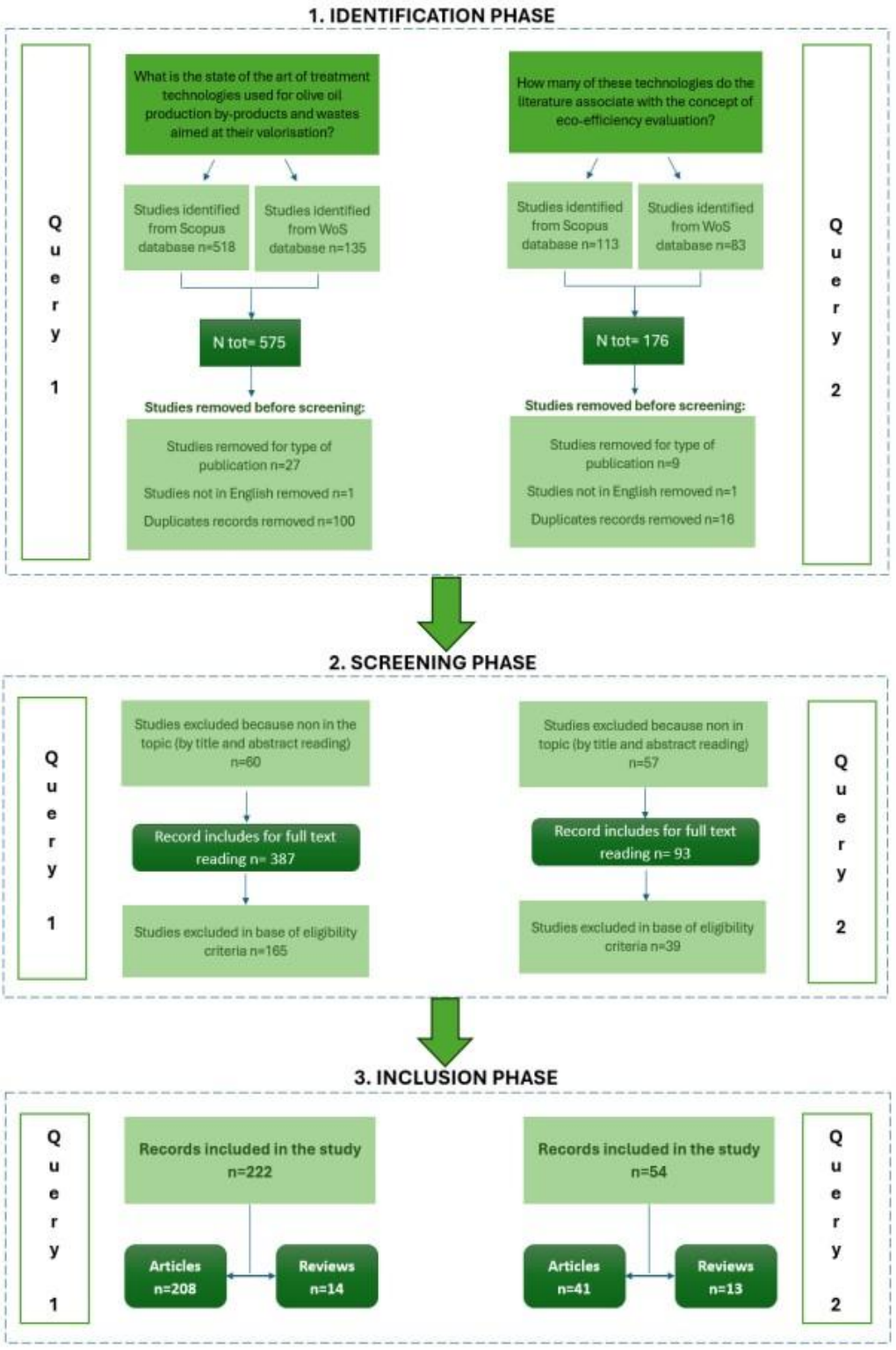

Figure 1: Search strategy based on PRISMA protocol

Results and Discussion

Results and discussions for query 1 and query 2 are reported in this section separately. The first query discusses treatment technologies and valorisation strategies of olive oil wastes and by-products to obtain a literature panoramic point of view of these and their relative patterns.

Concerning the results that emerged from query 1, figure 2 reports the main treatment technologies considered in the literature sample selected. In this regard, the main treatment technologies highlighted is anaerobic digestion process (19% of the total sample), the aerobic biological process and composting rank second most studied (17%), followed by the nano-micro-ultra filtration membranes and reverse osmosis treatment (11%), bioremediation (10%) and thermal treatment which includes steam reforming, combustion, pyrolysis, gasification and hydrothermal processes (8%). Many authors in this analysis point out the efficiency related to the biological treatment (i.e., anaerobic and aerobic digestions, and composting), used to remove chemical oxidation compounds (COD) as well as phytotoxic compounds from olive oil wastes and by-products, especially in OMWWs (Zahi *et al.*, 2022). Generally, the total COD removed was in the range of 94.3-61.3% and the volatile solids (VS) removed between 92.8% and 56.1% for organic loading rates (OLR) between 0.8 and 20.0 g COD $L^{-1}{\cdot}d^{-1}$, also a reduction of 43.8% was achieved for polyphenolic content (Rincón *et al.*, 2009). Concerning biological digestion methods, better yields of removal of the toxic component from OMWWs can be obtained through the progressive dilution of this discharge with other organic liquid discharges, for example from municipal wastewater (Athanasoulia *et al.*, 2012) or other agri-food sectors (Calabrò *et al.*, 2018). Dilution allows a lowering of the toxic content for the anaerobic microorganisms addressed in the olive oil wastewater: in this way, higher yields can be achieved with less suffering for the microorganisms (Bovina *et al.*, 2021). Among these two digestion methods, the anaerobic one has aroused the interest of many researchers as it has shown promising degradation results, furthermore, the use of this method does not require elevated energy. In addition, the anaerobic final digestate could be addressed to compost production (Bernardi *et al.*, 2017). Nano-ultra and micro-filtration applications are frequent in the literature. These technologies allow an easy removal of high phenolic content (average of 90%), in OMWWs especially (La Scalia *et al.*, 2017). However, the membranes and cost-effectiveness removal yields of the phenolic component and organic matter depend on the filter membrane material and operating regimes used (Ochando-Pulido and Martinez-Ferez, 2012). In particular, the silicon carbide membrane used for the treatment of the olive oil mill wastewater has effective removals of 99% of total suspended solids (TSS), and 97% of lipids, and the removal of COD and TOC was moderate (Zahi *et al.*, 2022). However, there are also membranes in ceramic materials (for ultra-filtration) that succeeded in the separation of high molecular weight constituents including lipid components (up to 90%) and a large amount of the phenolic compounds (average of 50%) (Ochando-Pulido and Martinez-Ferez, 2012). A technical issue associated with the use of nano-ultra and micro-filtration membranes and reverse osmosis is the control membrane fouling concerning the high organic load rate in OMWWs. For this reason, many authors highlighted the importance of including the dilution steps or also improving the pre-treatment step for lowering the organic load. Important is also the parameter setting to avoid membrane fouling (Ochando-Pulido *et al.*, 2015). Therefore, nano-ultra and micro-filtration membranes and reverse osmosis may be considered suitable technologies due to their low energy cost, reliability, and reduced capital cost (Arvanitoyannis *et al.*, 2007). Another important treatment technology that emerged from this analysis was bioremediation with significant phenol removal resulting from OMWWs and solid waste (Diamantopoulou *et al.*, 2021). Different types of

bacterial and fungal consortia have been considered in the literature to achieve high purification yields for olive oil wastes and by-products, mainly for wastewater. Many of these consortia are derived from the soil itself or taken from other activated sludge (McNamara *et al.*, 2008). It is well known in literature the capability of mushrooms to grow in difficult and toxic environments such as olive oil waste and by-products rich in phenols and polyphenols, producing fungal biomass and also improving valuable metabolites such as bioethanol (Amaral *et al.*, 2012; Koutrotsios *et al.*, 2022; Laconi *et al.*, 2007). Bioremediation can also be carried out using microalgae (Fernández-Rodríguez *et al.*, 2022) to obtain biomass and the transformation of recalcitrant substances into substances useful for other purposes through their metabolism. Overall, in literature, bioremediation in OMWW by aerobic strains achieved the highest reduction in COD (up to 80%) and phenolic compounds (McNamara *et al.*, 2008). It is a treatment system that is gaining increasing consideration in the literature due to its ease of implementation, without the use of special additional structures, and its economic feasibility (Diamantopoulou *et al.*, 2021). In addition, the thermal treatments, aimed at energy recovery, were implemented to overcome the problem of olive oil wastes and by-products production (Caputo *et al.*, 2003). Many authors have highlighted the capability of these treatment strategies to reduce the environmental impact of wastes and by-products and to generate electric energy to be directed to the grid or used in olive mills (Arvanitoyannis *et al.*, 2007). In addition, these treatments have the advantage of operating with solid and liquid output, often also in the same moment. Unfortunately, these treatment technologies require space and large investments; for this reason, thermal treatments often are not suitable for small-sized decentralized applications (Caputo *et al.*, 2003). Moreover, the gas obtained from thermal treatment is not always of good quality and needs further purification steps (Arvanitoyannis *et al.*, 2007). Despite these problems, treatment technologies based on energy recovery are economically favorable (Caputo *et al.*, 2003).

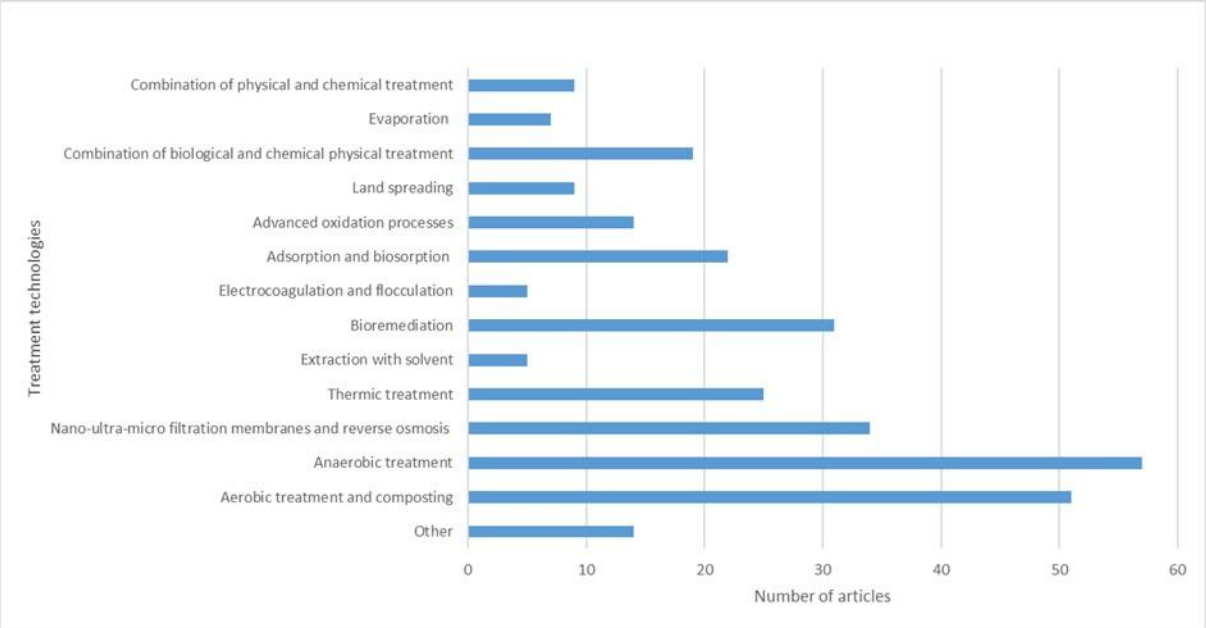

Figure 2. Identified technologies for olive oil wastes and by-products treatment among theinvestigated sample from query 1

The second aspect analysed in this query 1 study is the definition of valorisation pathways of olive oil waste and by-products for each type of treatment considered (figure 3). Given the high organic matter content of these wastes and by-products and the wealth of substances with high added value for human health that they contain, many areas for valorisation can be identified: from agriculture to energy, to the recovery of substances useful for food conservation (Zahi *et al.*, 2022), and therapeutic uses.

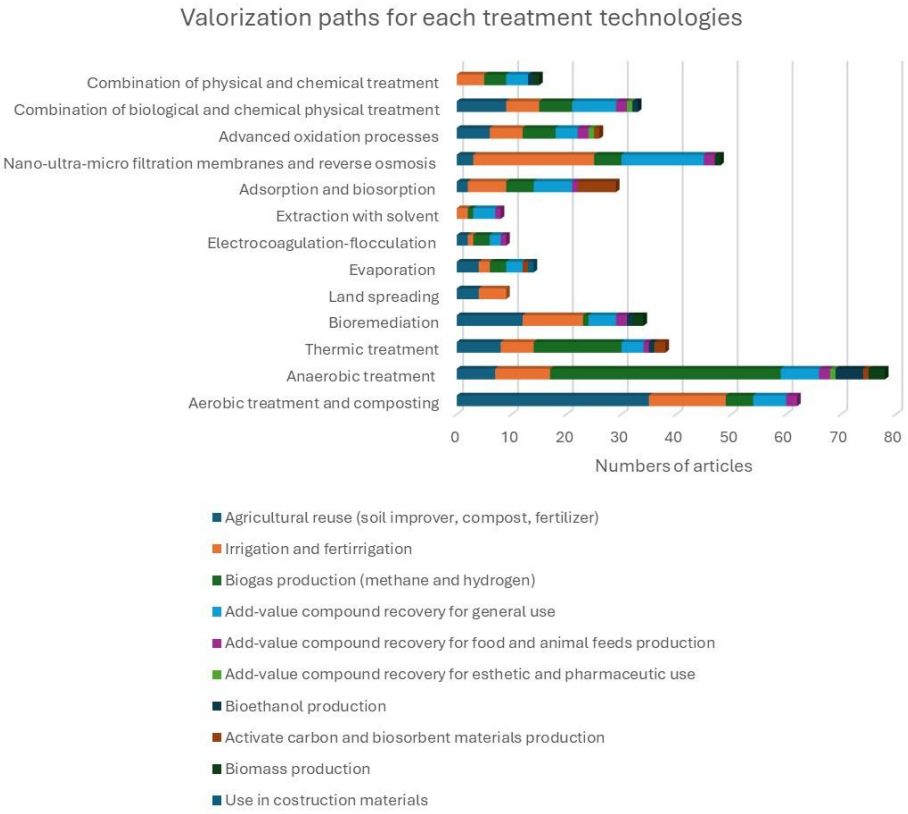

Figure 3. Treatment technologies and main valorisation routes emerged from query 1

Overall, the main valorisation strategies highlighted in this analysis are finalized to agricultural reuse for compost, fertilizer and soil amendment production, irrigation/fert-irrigation, as well as biogas production (including methane and hydrogen production) and added value compounds recovery for general use. The agricultural reuse of these waste and by-products is the most frequent valorisation strategy analysed among articles (35 papers). The biogas production through anaerobic digestion, for alternative energy sources is the second most frequent valorisation strategy (42 articles). In addition, a part of the sample under analysis (16 articles) includes biogas production obtained by thermal treatment processes. Generally, anaerobic digestion and thermal treatment are the most frequent treatments aimed at the production of biogas for alternative energy, but also considering the agricultural reuse of coproducts obtained from these treatments (i.e., biochar, and digestate). Another important strategy for the valorisation of these wastes and by-products is the recovery of high value-added substances, including polyphenolic substances, which is easily achieved through nano-micro and ultrafiltration and reverse osmosis, especially for OMWWs. In particular, in the latter case, filtered OMWWs are then frequently

used for irrigation. Many studies in the literature have addressed the issue of integrating olive oil waste and by-product recycling in agriculture production systems for improving sustainable development, especially in Mediterranean areas cause of the depletion of total organic matter and nutrients and drying up every year because of climate change. Maintaining soil fertility is one of the major challenges facing food production systems. Despite the toxic nature of olive mill wastes and by-products, they have a highly interesting fertilizing profile with high organic matter, and macro and micronutrients such as phosphorus, nitrogen, and potassium (Bouhia *et al.*, 2023; Shabir *et al.*, 2023). Consequently, the agricultural reuse of this waste, as low-cost nutrient agri-input, is one of the most considered valorisation approaches. The toxic nature of these wastes is mainly associated with the abundant presence of phenolic and polyphenolic substances. These last compounds are also persistent and not easily degradable by the microorganism during biological digestion for compost production. Therefore, many studies have focused on the removal efficiency of this phenolic component, or a large part of it, to ensure a highquality compost (Bouhia *et al.*, 2023). To achieve this, especially for aerobic treatment, in literature there is the 'co-composting' process, namely the biological aerobic treatment of olive waste and byproducts together with other agri-food biological discharges to have dilution factors useful to allow the microorganism to survive and have high treatment efficiency (Cayuela *et al.*, 2010). The main problem associated with this strategy of valorisation is the necessity of large spaces where organic waste is left to rest for the entire composting time (Bouhia *et al.*, 2023). In addition to the co-composting process to improve microorganism activity, some authors have also highlighted other techniques useful for the recovery of the phenolic component before the biological process. For example, the use of membranes for nano-ultra-micro-filtration and reverse osmosis, even though preferentially for the treatment of liquid inputs, is typically associated with anaerobic treatment for improving biogas production yields and also obtained recovery of polyphenolic compounds (Bovina *et al.*, 2021). The digestate obtained through the treatment could be applied directly as fertilizer without the necessity of stabilizing it in an aerobic process (e.G, composting) because the volatile substances can be reduced by up to 80% during previous membrane filtration and anaerobic processes (Pluschke *et al.*, 2023). Other studies have considered the use of microorganisms that are more resistant, or more adaptable, to the toxicity of polyphenolic compounds (Calabrò *et al.*, 2018). Some potential challenges associated with biogas production include the limited adaptability of current biogas technologies for small and medium-sized companies, and their high cost of investment and maintenance (Bouhia *et al.*, 2023). For this reason, small and medium-sized enterprises often rely on external digestion plants. Despite these considerations, many authors have considered biogas production one of the most realistic solutions for long-term sustainable olive oil waste and by-product management. Another important valorisation strategy that emerged in this analysis is the add-value compounds recovery from olive oil waste and by-products. Indeed, these contain different bioactive molecules such as polyphenols, anthocyanins, tannins, flavonoids, and pectin can be recovered and reused for several purposes in different fields of interest due to their outstanding biological properties (Nardella *et al.*, 2023). Some of these properties are, for instance, antioxidant, antiinflammatory, and anti-cancerogenic activities (Edgecombe *et al.*, 2000; Jimenez-Lopez *et al.*, 2020). For this reason, many studies have focused on the recovery of these useful substances that can be used in the pharmaceutical sector, but also in the cosmetic and food production and preservation sectors, for example for improving the quality of food (Pampuri *et al.*, 2021; Sar *et al.*, 2020), and to produce bioplastics useful for food preservation and packaging (Khwaldia *et al.*, 2022). It is important to bear in mind that the composition and quantity of these useful substances depend on agronomical and climatic factors during the cultivation

and also on the extraction processes (Nardella *et al.*, 2023). Several treatment technologies emerged in this systematic analysis of query 1 to promote the recovery of these substances, especially the phenolic and polyphenolic ones. Some studies focused, for example, on liquid-liquid extraction processes, considering ethanol (Lafka *et al.*, 2011) or ethyl acetate (Al-Qodah *et al.*, 2022) as the main extracting solvent, that due to its toxicity, may be substituted by natural solvents, such as the Deep Eutectic Solvents (DES) (Rodríguez *et al.*, 2006). In addition, the adsorption using selective adsorbent has shown a high percentage recovery of phenolic compounds from olive oil waste and by-products but the recovery but more research is needed to optimize these lab or pilot plant scale processes (Al-Qodah *et al.*, 2022). However, as the analysis also showed, nano-ultra-micro filtration and reverse osmosis membranes were found to be more efficient, cost-effective, and more eco-sustainable than conventional extraction technologies (Al-Qodah *et al.*, 2022). In addition, some articles include bioremediation treatment for the recovery of high-value-added substances by biological enzymatic activity. Indeed, the enzymatic activity of microorganisms could be useful for transforming organic compounds contained in olive oil waste and by-products, such as cellulose and lignocellulose, into bioethanol (Battista *et al.*, 2016). Furthermore, integrated treatments, whether biological, physicalchemical or purely physical-chemical, are highly efficient in increasing treatment efficiency and improving the valorisation of the waste and by-products considered. Indeed, some authors highlight the importance of combining nano-micro-ultra filtration membrane technologies with biological processes to preventively remove the toxic organic component, which is also the highest add-value one, to achieve high biogas and compost production yields (Bovina *et al.*, 2021). Therefore, the use of integrated treatments can provide many more opportunities for valorisation, even in the context of the circular economy.

The second query discusses the eco-efficiency approach and its evaluation for each treatment technology and relative consideration along with circularity and environmental sustainability, in order to know in detail how literature considers these aspects from an integrated point of view.

Query 2 analysis involved a theoretical or integrated eco-efficiency assessment for the different treatment technologies. Overall, out of a sample of 54 papers, it was acknowledged that 35 papers (65% of the literature sample) included eco-efficiency approaches in general, and 39% (19 articles) did not include eco-efficiency at all. In detail, among the studies that discuss eco-efficiency, 33% are focused on a theoretical point of view, while 31% refer to the integrated approach. This overview already shows that many authors recognized the importance of defining high-efficiency treatment technologies and valorisation for olive oil waste and by-products and assessing their respective environmental impacts, even without a standard definition of eco-efficiency. Thus, explains the most abundant presence of theoretical eco-efficiency approaches considered rather than integrated ones. This is shown also in figure 4 where different identified eco-efficiency approaches for each investigated treatment technology for query 2 are reported. Theoretical eco-efficiency approaches are considered in almost all treatments, except for bioremediation. In particular, the treatment technologies for which the theoretical ecoefficiency approach is more frequent are the thermal processes, the anaerobic and aerobic treatment, and the integrated treatments of chemical-physical technologies, nano-ultra, and micro-filtration membranes and reverse osmosis and solvent extraction of polyphenolic compounds. Meanwhile, the integrated ecoefficiency approach is highlighted especially for thermal processes, anaerobic digestion, and a combination of physical and chemical treatment. All other studies, that do not consider aspects of

environmental sustainability or that do not fall within the definitions of eco-efficiency proposed for this analysis were included in the "no eco-efficiency" category.

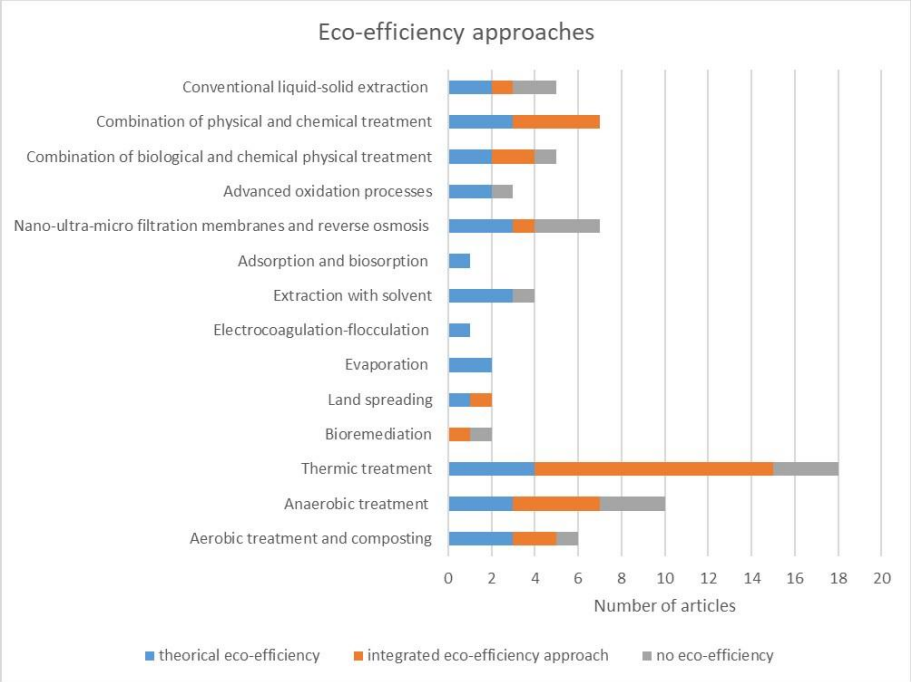

Figure 4: Trends in eco-efficiency approaches for olive oil wastes and by-product treatment technologies

To go deeper into how much eco-efficiency, in this context of analysis, is considered together with the circular economy and environmental sustainability, a further analysis was conducted and represented in figure 5. In particular, each treatment technologies in each article are evaluated from the eco-efficiency theoretical or integrated point of view and considering strategies of circularity (CE) and ecosustainability (ES) aspects to simultaneously highlight the main patterns in the query 2 sample. This analysis shows that the first approach considered for different olive oil waste and by-product treatment technologies is CE and ES strategies along with theoretical eco-efficiency. The second approach considered is CE with ES and integrated eco-efficiency approaches, with the definition of evaluation tools. The third approach highlighted is CE and ES described together but without eco-efficiency approaches. The main treatment technology that considers the combination of circularity, environmental sustainability, and integrated eco-efficiency approach is thermal treatment. This means that there is a strong pressure to make thermal treatments for energy recovery more environmentally sustainable and efficient. Many authors that focused attention on thermal treatment technologies have adopted the Life Cycle Assessment (LCA) methodology for assessing eco-efficiency approaches with CE and ES points of view (i.e., Dahdouh *et al.*, 2023; Ozturk *et al.*, 2023; Parascanu *et al.*, 2018). LCA, indeed, in literature is widely recognized as a suitable method for measuring not only the release of emissions and waste into the environment ecosystems but also the resource use and assessing environmental impacts and benefits, focusing on a life cycle perspective (Ncube *et al.*, 2022). These results allow us to identify a trend of increased interest in the combined approaches of circularity, environmental sustainability, and ecoefficiency, especially for thermal treatment and energy recovery. Many authors, for different types of treatment, already see a

natural integration of these approaches, even though there is a lack of standard definitions of eco-efficiency. Indeed, many articles remain on a theoretical treatment of eco-efficiency.

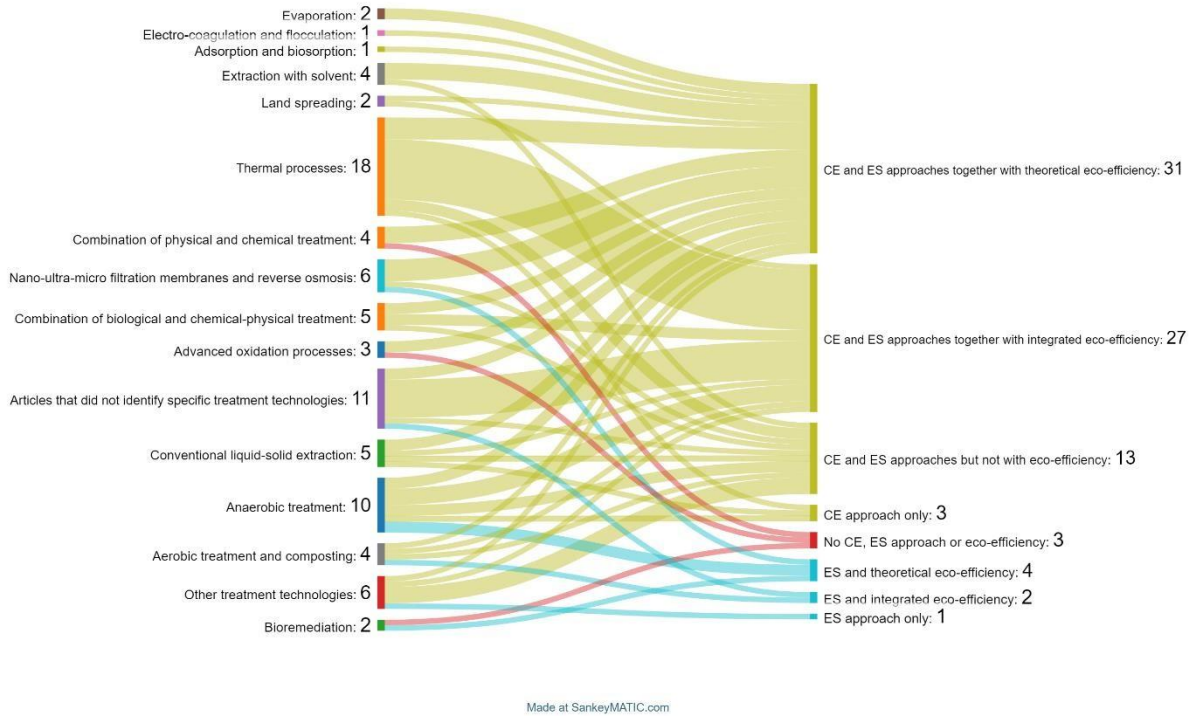

Figure 5. Trends that emerged during the analysis of circular economy (CE) and environmental sustainability (ES) aspects together with theoretical or integrated eco-efficiency approaches for olive oil waste and by-product treatment technologies.

Furthermore, the main circularity strategies are associated with the valorisation of olive oil wastes and by-products and the pollution footprint reduction in these (Klisović *et al.*, 2021). Overall, these findings have highlighted the strong push that literature had to search for new systems of integration between treatment and valorisation, economic advantage, and environmental benefits.

Conclusion

The present study provides a systematic review of the literature analysing the state-of-the-art of waste and by-product treatment technologies in the olive oil supply chain, focusing on valorisation strategies and the evaluation of their eco-efficiency. The systematic review was conducted through the analysis of two research questions: i) 'what is the state of the art of treatment technologies used for olive oil production by-products and wastes aimed at their valorisation?'; and ii) 'how many of these technologies do the literature associate the concept of eco-efficiency?'. In order to answer these research questions, two queries were developed, query 1 and query 2 for both Scopus and the Web of Science database research. The results that emerged from the first query highlighted what are the main treatment technologies for processing olive oil wastes and by-products and their main ways of valorisation. In particular, the treatment technologies mainly considered in

the literature were anaerobic and aerobic digestion, followed by nano-micro-ultra membrane filtration and bioremediation and thermal process systems. This, in turn, has highlighted the strong propensity of the literature towards ways of valorisation for agricultural and energy reuse and recovery of polyphenolic compounds. The analysis of query 2 revealed how many of these technologies are considered from an eco-efficiency perspective, even though the term eco-efficiency does not emerge directly in the studies. The theoretical eco-efficiency approach was found to be more frequent than the integrated eco-efficiency. This means that many authors recognized the importance of defining high-efficiency treatment technologies and valorisation strategies for olive oil waste and by-products and assessing their respective environmental impacts without considering a specific indicator for eco-efficiency evaluation. This last aspect could be related to the lack of a standardized definition of eco-efficiency and its analytical tools in the literature. Furthermore, query 2 analysed the trends that emerged during the analysis of circular economy and environmental sustainability aspects together with theoretical or integrated eco-efficiency approaches for each treatment technology. The main pattern highlighted was the circular economy and environmental sustainability principles considered together with theoretical eco-efficiency approaches, and the second more frequent approach considered was circular economy and environmental sustainability and integrated eco-efficiency approaches, with the definition of evaluation tools. In particular, in these last trends, the main treatment technologies considered were thermal processes, highlighting a strong interest in making thermal treatments for energy recovery more environmentally sustainable and eco-efficient in an integrated way. Many of these studies focused attention on olive oil waste and by-product treatment technologies that considered energy recovery as a valorisation strategy, to ensure a closing resource loop in the companies. Therefore, during this systematic literature review, many different types of treatment and many different valorisation strategies emerged, making it difficult to categorize the data and recognize patterns between treatment technologies, valorisation, and types of wastes and by-products. However, these findings allow mapping the state of the art of olive oil waste and by-product treatment technologies, valorisation strategies, and the evaluation of their eco-efficiency in a contest of the circular economy and environmental sustainability. Further studies, it is expected to evaluate in detail the methods and indicators to measure the eco-efficiency of olive oil waste and byproduct treatment technologies in companies together with eco-sustainability and circularity. Starting from these results, it will be developed a dedicated framework aimed at allowing the identification of the most appropriate technologies as well as the assessment of their related eco-efficiency, focusing on an environmental sustainability and circular economy perspective which supports companies in choosing the appropriate treatment strategies to adopt for olive oil wastes and by-products.

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Posters

Submission ID: 318

Stocks and Flows of the Non-Negligible Toxic Polybrominated Diphenylethers (BDE-209) In the Chinese Automobile Industry

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Abstract

BDE-209 is a persistent organic pollutants (POPs) and extensively used in the automotive sector as a legacy brominated flame retardant. Recycling materials from end-of-life vehicles are a crucial component of the circular economy, but it contains high levels of BDE-209, posing significant risks to human health and the environment. This study aims to estimate the stock, flow, emission and associated environmental impact of BDE-209 throughout the life cycle of vehicles in China from 2010 to 2050. A dynamic substance flow model and scenario analysis were applied to estimate the substance flow of BDE-209, and life cycle assessment was adopted for toxicity assessment of human health based on vehicles types, lifespan, BDE-209 contents, and emission factors. Results show that in 2020, 7,370 tons of BDE-209 newly entry into the in-use phase, with 60% flowing up to the scrap stage (4,402 tons) and 29 % re-entering the social system through material recycling. Sedan and Sport Utility Vehicle (SUV) were the main contributors to both in-use and scrap stages, with contributions of 40%-44% and 23%-58%, respectively. The emissions of BDE-209 were projected to rise to 7,854 kg by 2050, an 11-fold increase from 2010. The atmosphere and soil are the primary environmental media for emissions, with distribution rates of 56% and 33%. Human health toxicity mainly comes from the in-use stage, followed by automobile shredder residues treatment (ASR) and reuse stages. Future reduction strategies, such as enhancing the recovery rate of scrapped vehicles and refining ASR treatment could potentially reduce BDE-209 increment by 1,232 kg and 1,793 kg in 2030 and 2050, respectively. Furthermore, soil is projected to replace the atmosphere as the primary medium for emissions. Analyzing human health toxicity excluding the use phase, implementing reduction strategies can effectively mitigate toxic effects, with approximately a 33 % decrease under the medium reduction scenario and an 18 % decrease under the high reduction scenario. The study highlights the necessity of considering toxic substances in the current automotive circular economy from a life cycle perspective and provides a reference for reducing BDE-209 emissions in the automobile industry.

5d. Value Chains and Trade

Abstracts

Submission ID: 39

Strategic Sourcing for Enterprises in a Geopolitically Insecure World - Securing the Supply of Critical Raw Materials

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Abstract

The 21st century is characterized by countless technological inventions, innovations, and groundbreaking technologies spanning various domains from personal life to businesses and military applications. Key technologies permeate diverse sectors, and headlines increasingly feature terms such as semiconductors, drones, quantum computers, or artificial intelligence. These key technologies share a commonality—they operate only with sufficient power and the necessary hardware resources. The requisite energy transformation away from fossil fuels towards renewable energies depends on the availability of critical raw materials. Almost all key technologies, including photovoltaic technologies, rely on silicon. However, like many other critical raw materials, silicon is predominantly mined, refined, and exported from China. China also controls many downstream production chains within the photovoltaic industry. In the past, China has leveraged its power position in exporting critical raw materials through production quotas, export quats, and export taxes exerting political pressure on other countries. This not only jeopardizes international security but also the availability of key technologies and the success of energy transformation. Raw material dependencies and uncertain market conditions result in various sourcing scenarios with associated costs. Using the example of silicon, this study tests the cost implications of dynamic supplier limitations and spot market price fluctuations. Consequently, two research questions arise: What are the impacts on procurement and inventory costs due to critical supplier availabilities and fluctuating spot market prices in strategic silicon sourcing? What sourcing implications can be derived for the economic sustainability of companies in uncertain market environments? To model the associated decision problem, the Multi-Sourcing Single Item Capacitated Lot Sizing Problem is employed. To incorporate the increasing geopolitical impacts on markets, the model represents order criticality in the form of the Worldwide Governance Indicators (WGI) and the relative quantity share in production demand. To adequately evaluate the results, a scenario analysis is conducted through simulation-based optimization, comparing selected sourcing scenarios against a benchmark. In total, 21 different scenarios are considered.

The results indicate that the higher the spot market fluctuation, the lower the supplier dependency. The sourcing problem is subject to certain limitations, including static supplier contracts, absence of quantity discounts, and a static cost rate ratio. From an economic perspective, for companies, dependencies on suppliers and their limitations decrease with higher spot market price fluctuation. Consequently, there is a future need for robust planning methods in spot market procurement, especially in unpredictably volatile commodity markets. Furthermore, there is a perceived research need to investigate whether spot markets are a reliable source for critical raw materials in geopolitically uncertain markets.

The results obtained through this study could contribute to the achievement of SDGs 7.1 and 8.2. This is manifested in the assurance of expanding renewable energy sources and the associated availability of critical raw materials, while concurrently facilitating an enhancement in industrial productivity. Furthermore, it contributes to a more comprehensive consideration of geopolitical changes in the upcoming years, which can indirectly jeopardize the success of all SDGs.

Submission ID: 181

Sustainability Data Sharing in Supply Chains – Empirical Insights from a Global Industry Survey

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Abstract

The exchange of sustainability-related information along value chains is a key requirement for a successful transition to more sustainable patterns of production and consumption. It enables companies to gain insights into the sustainability practices of their suppliers, conduct sustainability assessments, and make sustainability and circularity-related decisions during product and service design. However, while new digital technologies such as digital product passports or dataspaces provide possible solutions for a more efficient flow of information that is increasingly also required by regulations, empirical evidence on the state of data exchange along global value chains is limited and mainly available in the form of case studies. Therefore, this study sets out to assess the extent to which companies exchange sustainability-related information along the value chain and explore their motivations and barriers to this exchange.

A quantitative online survey was used to investigate companies from various industries and different sizes around the globe. The data was analyzed using descriptive and inferential statistical methods to assess the answers from 675 companies. The findings show that 61% of the respondents regarded sustainability as highly important globally, with statistically significant ($p < .001$) differences between regions (i.e., Asia and Europe, Asia and North America, Central/South America and North America and Central/South America and Europe), as measured by a Kruskal-Wallis test. The majority of the survey companies (i.e., 78 %) report that they share data on the sustainability status of their products with customers, with significant differences ($p < .05$) regarding the company size. As expected, large companies share significantly more than medium or small companies. Most often, companies share Environmental Product Declarations (i.e., 48 % of the companies that share data), followed by Product Carbon Footprints (23 %), full Life Cycle Assessments (16 %), and Water Footprints (7 %). Of the 146 companies that do not share sustainability data, 28 % stated that they do not receive requests from customers, 21 % that they do not have sustainability data available, and 20 % that they do not share data with third parties at all. Finally, the survey reveals a growing trend in regulatory and customer demands related to product data. Almost half of the surveyed companies (i.e., 49%) perceive an increase in regulations enforcing the exchange of sustainability data in the last years. Slightly more than half of the surveyed companies (i.e., 55 %) are facing an increase in customer requests for sustainability data, and 61 % experience an increase in compliance-related data requests.

In summary, while sustainability data sharing was found to be a common global practice that is increasingly driven by regulations and customer pressure, its focus is still limited. Thus, it is crucial that this focus is expanded to enable a more comprehensive management of the sustainability performance of products and organizations. Such enhanced data exchange is not only required for achieving SDG 12 and targets 12.6 and 12.8 but also for achieving sustainable livelihoods, as it facilitates informed decision-making and increases transparency and accountability across industries.

5e. Sustainable Consumption and Consumers

Abstracts

Submission ID: 38

Circular Value Chain Blind Spot: A Scoping Review of the 9R Framework in Consumption

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Abstract

In today's highly digitized age, where advancements in communication and efficiency coincide with increased resource consumption for hardware production, the prevalence of digital media and electronic products contributes to a vast array of diverse products. The rapid influx of new electronic devices fosters market dynamism, driven by consumer incentives to possess the latest products, perpetuating a linear economy in the electronics industry. Unfortunately, this has resulted in a significant surge in Waste of Electrical and Electronic Equipment (WEEE), making it the fastest-growing waste category. To counter this concerning trend, establishing a circular economy (CE) emerges as a viable solution. Within this framework, consumers play pivotal roles, potentially prolonging device lifespan and conserving resources. However, existing research predominantly focuses on recycling, with the remaining 9R framework strategies receiving limited attention. These strategies collectively constitute a theoretical concept within the CE.

This study aims to provide a detailed overview of current research on consumer behavior regarding e-waste, utilizing the 9R framework. Two research questions guide the investigation: What aspects of the circular and linear economies are systematically investigated concerning consumer behavior in handling WEEE? What strategies are recommended for consumers or consumption to strengthen circular behavior in line with the 9Rs? To address these questions, a Scoping Review methodology was employed. Using search terms in databases such as Scopus, Web of Science, and ProQuest, 122 articles were reviewed, with a focus on online panels, questionnaires, and interviews with consumers regarding their interactions with WEEE. Additionally, the strategies provided by authors for improving the CE were analyzed.

Results indicate a majority of research concentrating on recycling behaviors and disposal/storage habits, with other 9Rs receiving limited attention. Furthermore, strategies for enhancing the CE primarily target governments and businesses, with consumers recommended only education. This results in blind spots, neglecting crucial aspects of the CE, referred to as the Circular Value Chain Blind Spot. To address this, an agenda with practical implications has been developed, including directives such as nudging, differentiation, a systematic perspective, waste hierarchy, value chain strategies, and cultural factors. Findings are subject to limitations: not all relevant articles may have been captured, selection criteria may have influenced the number of articles, and generalizability is confined to the WEEE sector.

In conclusion, there is limited knowledge within the CE about consumer behaviors in various subdomains within the electronics industry. The identified Circular Value Chain Blind Spot characterizes this condition and should be addressed through the proposed agenda to conserve resources and reduce the accumulation of WEEE.Overcoming Circular Value Chain Blind Spots has the potential to enhance resource efficiency (SDG 8.4) and bolster the protection of labor rights (SDG 8.8). Additionally, it can contribute to the reduction of waste generation (SDG 12.5) by gaining insights into people's behaviors regarding a circular economy within the WEEE sector. Furthermore, by diminishing the WEEE output, it may mitigate the degradation of natural habitats (SDG 15.5), as a reduction in informal recycling could lead to fewer pollutants being released.

Submission ID: 127

Moderating Effects of Environmental Concerns on Diet Preferences across Generational Cohorts

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Abstract

Meat is an important and growing part of diet worldwide. Meat consumption and production are widely discussed topics in the wider public forum due to their impacts on nutrition, sustainable food systems and climate change (Sanford, *et al.* 2021). This study seeks to answer two key questions – 1) how dietary behavior varies across generations? And 2) what role environmental concerns play in dietary choices across generational cohorts? The study is based on data collected in the 2019 LOHAS (Lifestyles of Health and Sustainability) database survey by Natural Marketing Institute (NMI). NMI is a health and wellness marketing Research Company that works with major industry clients including Nestle, S.C. Johnson, and Walmart among others. The 2019 data was collected online by surveying more than 3,000 out of over 60,000 U.S. consumer panel in September 2019. The data represented U.S. demographics relatively accurately with a 95% confidence level.

Results from the Model that included variables representing environmental concerns show that both high and moderate levels of environmental concerns have significant impact on diet choices compared to low level of environmental concerns. Those with moderate to high levels of environmental concerns were likely to prefer more plant-based diet.

Results from the Model that included base variables and generational cohorts show that respondents belonging to generation Z/Millennials and generation X were not significantly different from those belonging to boomer and silent groups. However, when environmental concern variables were added then those who are either generation Z or Millennials were less likely to prefer diets with more meat. The results in this case are consistent with the research hypothesis (H2) that the relationship between generational cohorts and diet preferences is possibly moderated by environmental concerns. It was expected that the intensity and direction of the relationship between generational cohorts and diet preferences are conditioned by environmental concerns. Following the results, the younger generations, in this case Gen Z and Millennials are likely to have high to moderate environmental concerns and prefer more plant-based diet. It is expected that this relation to be more intense when households show highest levels of environmental concerns than those with lowest level of environmental concerns.

Regression results show that differences between men and women on the basis of food choices remained consistent and did not change when variables representing generational cohorts and environmental concerns were added. Men were likely to select diet with higher meat content than women. Results showed regional differences in food choices. Households in the states included in the western region were significantly different from those in the south with regard to food choices. Households in the west were likely to select a more plant-based diet than those living in the south. Households in the Midwest and northeast did not show any such difference compared to households in the south. When generational variables were added the effects remained largely the same.

Submission ID: 171

Citizens' Deliberation on Solutions to Fight Urban Household Food Waste

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Abstract

Food waste is currently acknowledged as a major societal challenge, including the food waste at the household level estimated to be responsible for the wastage of one third of the food produced for human consumption. Hence, tackling Household food waste (HFW) has is gaining gained a momentum in societal and policy agendas accompanied by an increasing effort of the scientific community to deliver evidence to address the research gaps on the causes and on the solutions to address this multidimensional societal problem. The proposed solutions by published literature to mitigate HFW can be unfolded into four major types, actions to raise people awareness, participatory actions, economic incentives, and collective actions. However, there is little evidence on the household's assessment on the different types of actions and its combination. This paper contributes to this research gap by adopting an innovative participatory approach, using deliberative focus groups (DFG), and analyzing the collected data through content analysis resorting to the software Maxqda. Six DGF were conducted in the Porto metropolitan area before and during the pandemic COVID-19 crisis. The results highlight the citizen's selection for more holistic actions in comparison to separate actions to fight effectively fight food waste at household level. Another finding of the study is that citizen's growing urban gardens found it more effective way to reduce own food waste. These results suggest that urban policies and underlying legal frameworks should favour holistic solutions to incentivise fighting HFW and account for the urban gardens. In addition, the study has shown that qualitative deliberative citizen-led approaches show insightful to understand how common people perceive as alternative or complementary different types of actions proposed by the literature review.

Submission ID: 172

Factors Influencing Environmental Behavior: A PLS-SEM-Based Approach

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Abstract

Environmental behavior has long been studied linked to environmental knowledge and attitudes. Although there are debates related to the causal effect between these topics, most studies agree on a positive relationship between them (Casló & Escarion, 2018; Liu *et al.*, 2020). However, less emphasis has been put so far on how more general attitudes (like simplicity or frugality) influence environmental behavior.

The core hypothesis of this submission is that beyond specific, environmental and sustainability attitude-related factors, more general ones (like frugality) also influence environmental behavior.

A PLS-SEM research model is developed focusing on direct and indirect impacts of factors like environmental activism, frugality and conservation behavior on environmental behavior. For the model building, the review of Milfont & Duckitt (2010) on environmental attitude measures were used as a basis, while environmental behavior was based on the scale of the Eurobarometer survey. For testing the hypotheses, a Hungarian sample (size of 1000 respondents) is used that is representative for age, gender and education.

Results support the main hypothesis in the sense that beyond the sustainability-related attitude factor (environmental activism) the more general one (frugality) also positively influences environmental behavior. Furthermore, the latter applies not only directly, but also indirectly, through conservation behavior, a direction could not be validated for the factor of environmental activism.

These findings imply that environmental and sustainability behavior can not only be fostered through the 'mainstream' track (via promoting and educating environmental awareness and activism), but also through general patterns of a simpler and in general more conscious lifestyle, the impact of which is less often discussed so far.

This submission is related to specific UN SDG targets, such as 12.1., 12.5., and 12.8. On sustainable consumption. Furthermore, the topic of this submission is also directly related to the key theme of the current conference (rescuing the SDGs 2030 for sustainable livelihood), as it touches on the theme of sustainable consumption, a key challenge for higher income countries, as these countries serve in general also a benchmark for the rest of the world.

Submission ID: 186

Motivating Behaviour Change: Understanding Drivers for Radical Lifestyle Shifts and Reduced Meat Consumption

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Abstract

Current food consumption patterns contribute to approximately one-third of total anthropogenic greenhouse gas emissions (Crippa, 2021). Moreover, agriculture utilizes over 80% of arable land, with this figure continuing to rise. Substantial reductions in greenhouse gas emissions and associated environmental impacts of land use could be achieved by reducing meat consumption (Hallström *et al.*, 2015; Rancilio *et al.*, 2022).

While behavior change theories traditionally emphasize incremental, there is a growing need to understand high-impact, radical, and transformative lifestyle changes. The adoption of a vegetarian diet and reduction in meat consumption exemplify such radical lifestyle changes. In this research we explore various motivations of consumers and identify triggers which lead to behavioral changes of reduced meat consumption. We analyse feedbacks regarding potential negative aspects of dietary change. Fogg's (2009) behavior model serves as the theoretical framework of the analysis, which was previously employed in persuasive technology contexts.

The research is based on a survey of 566 participants active on social media platforms, with a particular focus on in-depth content analysis of responses to open-ended questions. Large-scale qualitative studies are scarce within the domain of sustainable consumption research.

Findings suggest that social media bubbles can serve as triggers for building capabilities, facilitating the dissemination of new consumption patterns, reinforcing positive impulses, and screening out negative ones. Additionally, personal experiences emerge as influential drivers of radical lifestyle changes.

Results show a reversal in knowledge transfer between generations, with children often influencing their parents' behavioral patterns. Notably, discouragement and critical feedback predominantly originate from family and close acquaintances. The negative effects of social media are mitigated by the bubble-filtering effect, allowing for the identification and avoidance of adverse influences.

Understanding the motivating factors, triggers, and potential barriers to radical lifestyle changes is essential for designing effective interventions and transforming unsustainable consumption patterns.

The research is closely related to SDG Goal 12: Responsible consumption and production, sub-target 12.3 and 12.8, and SDG 3: Good health and well-being. Results are closely linked to the topic of the ISDRS 2024: Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood conference, as the focus of the research is to understand the behaviour change of consumers for a more sustainable lifestyle and reduced environmental impact.

5f. Food System Transformation

Abstracts

Submission ID: 10

Peak and Fall of China's Agricultural GHG Emissions

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Abstract

Agriculture takes a large proportion of greenhouse gas (GHG) emissions, playing an essential role in achieving global climate goals. However, targeted mitigation opportunities for agricultural GHG are still unclear due to the lack of standalone analyses at sub-national and food-specific scales. Here, we accounted for agricultural GHG emissions in 2000-2020 in mainland China and found that the largest emission sources by region, product group, process, and gas were Hunan province, rice cultivation, enteric fermentation, and CH_4, respectively. Agricultural emissions peaked in 2015 and temporarily declined by 8% by 2020 and possibly decline by 30-36% by 2060, primarily owing to the reduction potential from meat production in eastern and northern China. The emissions produced and land needed per unit of food product reduced mostly, while emissions per unit of land use increased in many regions and food groups. We conclude that the opportunities and challenges for GHG mitigation lie in a few top emitters in central China where intensities were unexpectedly much larger than the levels of the national average and marginal agriculture in the northeast.

Submission ID: 65

Urban Agriculture Matters for Sustainable Development

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Abstract

Urban agriculture can contribute to sustainable development. However, a holistic investigation is lacking to comprehend its positive and negative impacts on the Sustainable Development Goals (SDGs). We fill this gap with a systematic analysis of around 1,450 relevant publications on urban agriculture, screened from 76,000 initial records. We map and analyze the text in the literature for each SDG target and associated positive or negative sentiments. All SDGs are positively and negatively linked to urban agriculture, with 142 and 136 targets having positive and negative sentiments. The mapped texts with positive sentiments are around double the negative ones. We identify six leveraging opportunities urban agriculture provides for sustainable transformation with four hurdles to be resolved. Urban agriculture, in itself, does not inherently contribute to sustainability. Its impacts rely on the adoption of specific practices. Realizing urban agriculture's social, economic, and environmental functions to accelerate SDG progress requires tackling the hurdles.

Submission ID: 95

Do Farmland Transfers Mitigate Farmland Abandonment? A Case Study of China's Mountainous Areas

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Abstract

Farmland abandonment is a manifestation of farmland misallocation in mountainous parts of China. Farmland transfers are an important pathway for reallocating farmland, and it is still unclear whether farmland transfer can mitigate abandonment and what factors affect the relationship between the two. Thus, according to the principle of resource market allocation, this study constructed a theoretical model that included labor force, farmland resources endowment, and the land market. Combining unique survey data (539 samples), we used Tobit, IV-Tobitl, the interaction impact, and moderation effect models to analyze the effect of farmland transfers on abandonment at the village level. We found that farmland transfers could mitigate abandonment. The farmland abandonment rate declined by 0.09% when the transfer rate increased by 1%. For areas with fewer full-time agricultural labors, abundant farmland resources, more high-quality farmland, and more transfers with paid rent, the impact of farmland transfers on abandonment was greater. Village cadres also believed farmland transfers could mitigate abandonment, and viewed labor force resources and farmland resource endowment as important factors affecting abandonment. This study helps to deepen the understanding of the relationship between farmland transfers and abandonment, and serves as a basic scientific reference for corresponding policy suggestions on how to enhance the effect of farmland transfers.

Submission ID: 102

Alternative Food Movements as Contested Vehicles for Climate Justice

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Abstract

The global food security literature focuses on the health, social, and environmental impacts of industrial food systems and portrays alternative food movements (AFMs) as immune to injustices. This study aims to synthesise evidence on an under-researched area of food systems, especially the social and environmental justice implications of the AFMs globally in all possible contexts and dimensions using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). The search keywords cover five dimensions of justice – distributive justice, procedural justice, recognitional justice, restorative justice, and cosmopolitan justice - in alternative food movements and involved three databases (Scopus, Web of Science, and Medline). A narrative synthesis was performed to identify the themes. A total of 140 peer-reviewed studies met inclusion criteria and were subjected to topic modeling. Our analysis highlighted the 'triple movement theory' (corporate food movement, alternative food movements, and food justice movements) resulting in nine topics under two themes (representing technical as institutional aspects) to address multiple, multispecies, and planetary injustices in food systems. The available literature on alternative food movements began to address multiple food injustices primarily in the context of developed countries since the early 1990s indicating that there is a dearth of knowledge in the literature, particularly the more than human approaches to multispecies, cosmopolitan, and planetary justice in global food security.

Submission ID: 126

Effects of Climate Change and Adaptation Strategies on Food Security: Lessons from Nepal

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Abstract

Globally, a significant proportion of food insecure households are smallholder farmers. This study focused on the role of climate change and adaptation strategies on food security of smallholder households in Nepal. Data were collected in 2021 from 400 farming households from three agro-ecological zones of Nepal, namely Mountain, Hilly and Terai. Indicators of food consumption score and reduced coping strategies index showed that about 12% and 22% of the farming households belonged to the food insecure group. Ordered logit models show that climate change (drought) has a negative impact, while climate change adaptation strategies (irrigation, agroforestry, and temporary migration) have a positive impact on food security status. The results also show that education, access to markets, credit and information affect household food security. We recommend that any adaptation strategies to address food insecurity should be carefully designed to fit the socio-economic, climatic, and institutional structures of each agro-ecological zone.

Submission ID: 216

Spatial Differences of Specialty Agriculture Development in the Mountainous Areas of China: 'One Village, One Product' as an Example

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Abstract

With the rapid development of urbanization, the rate of abandonment of arable land in China's mountainous areas has accelerated. Solving the phenomenon of abandonment of arable land has become an important issue in managing the use of China's arable land, the key to which lies in the development of specialty agriculture using the unique natural environment of mountainous areas. This paper scrutinizes both the horizontal and vertical distribution of specialty agriculture in these areas, drawing upon the "One Village, One Product" dataset provided by the Chinese Ministry of Agriculture and Rural Development. The findings reveal that the horizontal distribution pattern of specialty agriculture exhibits the formation of eight primary clusters. It is intriguing to observe that a majority of these clusters are situated at the intersection of two or three provincial administrative units, with the largest cluster occurring at the border of Chengdu and Chongqing. In terms of the vertical distribution pattern, the specialty agriculture in China's mountainous areas are mainly distributed at low altitudes, i.e., below 500 m, and at gentle slopes of 4°-8°, and with increases in altitude or slope, the overall amount of specialty agriculture declines rapidly.

Full Papers

Submission ID: 17

Assessing the Environmental Impact of Strawberries Grown in Soilless Systems: A Life Cycle Assessment Case Study

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Abstract

Modern agriculture faces pressing challenges that threaten environmental sustainability. One promising approach to address these challenges lies in the adoption of soilless cultivation systems. These systems replace soil with growing mediums (liquid or solid) and provide plants with nutrients through a nutrient solution, eliminating the need for tillage and minimizing soil degradation. However, concerns have been raised regarding their environmental impacts, which can vary depending on the technology and infrastructure employed. In this article an LCA case study of soilless strawberry cultivation in Maletto (Italy) is proposed to evaluate the environmental burdens connected with this system. The functional unit is 1 kg of strawberries, and the system boundaries are defined as cradle-to-gate. The inventory analysis is carried out using primary data collected through direct interviews and questionnaires submitted to the farmer, and secondary data from literature and dedicated databases. The impact assessment is performed using the CML I-A baseline and IPCC methods. Preliminary results led to identify fertilizers, substrate bag and transport to farm as major hotspots. Further research will be focused on a comparative study between soilless and soil-based strawberry cultivation systems to fully assess their relative environmental impacts and inform sustainable agricultural practices.

Keywords*: strawberries; soilless systems; Life Cycle Assessment; hot-spots analysis; agrifood*

Introduction

Agriculture continues to be a cornerstone of human progress, serving as a source of essential resources for expansion, such as food and fuel (Payen *et al.*, 2022). However, with global population numbers expected to reach 8.5 billion within the coming years, there is an increasing concern over the relentless demands placed on food production. This could result in food scarcity, potentially exacerbating cases of malnutrition and hunger (FAO, 2021). The quest for increased agricultural output is intensifying the competition for land, which may lead to the conversion of more forests into farmland, thus triggering ecological concerns (Muscat *et al.*, 2020; Payen *et al.*, 2022). In addition, such pressures compel farmers to push land resources beyond their limits to achieve greater yields, often resorting to the use of agrochemicals and practices in soil and water management that may harm the environment. The use of these chemicals in farming significantly contributes to the eutrophication and acidification of both water bodies and land, while poor management of soil, water, and agricultural waste exacerbates pollution, diminishes soil fertility, and leads to the contamination and depletion of groundwater reserves (Popp *et al.*, 2014; Clark and Tilman, 2017).

Nonetheless, a potential solution can be found in controlled environment agriculture (CEA), where parameters key to crop growth, such as temperature, illumination, nutrients, and moisture levels, are artificially regulated (Casey *et al.,* 2022). CEA typically employs soilless cultivation systems. In a soilless

system, crops can grow without natural soil (contrary to conventional farming), instead they are nurtured in alternative growing medium (or substrates), which might be either a liquid solution full of nutrients or a solid one (Gruda, 2019). Solid substrates vary and can include those of natural origins like coconut fiber, peat, and compost, or synthetic ones like rockwool and perlite (Joshi *et al.,* 2022). Soilless system can offer potential benefits in terms of higher yields, reduced inputs and optimal growing conditions (Fussy and Papenbrock, 2022). In addition, in a soilless system, plants can grow unharmed by pests, minimizing or totally removing the need for pesticides (Manos and Xydis, 2019). These advantages align with achieving the Sustainable Development Goals (SDGs). Indeed, they may contribute to eliminating hunger (SDG-2) through increased crop yields and efficiency, promote good health and well-being (SDG-3) by reducing the use of harmful chemicals like pesticides, and support clean water and sanitation (SDG-6 and SDG-12) due to their efficient water usage, as well as and life on land and below water (SDGs 14 and 15) thanks to reduced land use and optimal use of fertilizers (Zhou *et al.,* 2021).

However, some authors pointed out that soilless systems can be perceived as complex and expensive (Payen *et al.* 2022), raising questions about their environmental impacts compared to conventional farming methods (Rothwell *et al.,* 2016). Furthermore, various crops have unique needs, resulting in diverse system configurations with distinct environmental implications (Armanda *et al.,* 2019). Additionally, while substrates such as perlite, peat, and rockwool offer advantageous physical characteristics for plant growth (Raviv *et al.,* 2002), their extraction and production processes can lead to significant environmental concerns. For instance, perlite extraction is energy-intensive, peat harvesting affects crucial carbon-sequestering peatlands, and rockwool fibers may present potential health hazards (Gruda, 2019; Toboso-Chavero *et al.,* 2021). Consequently, organic substrates are often favored due to their accessibility, cost-effectiveness, and simpler disposal methods (Barrett *et al.,* 2016), but their transportation raise environmental concerns (Toboso-Chavero *et al.,* 2021). Finally, soilless cultivation systems encompass a wide array of techniques, each with its own environmental impact. These impacts are also influenced by other factors, including the materials and equipment used, as well as regional climatic and economic conditions (Manos and Xydis, 2019).

Considering these shortcomings, it is advisable to employ comprehensive methodologies to analyze their environmental impacts (Armanda *et al.,* 2019). The most widely used method to assess holistically the environmental impact of soilless systems is Life Cycle Assessment (LCA) (Licastro *et al.*, 2024).

One leading fruit that thrives well in a soilless system is strawberry. Strawberries are recognized as an important part of the mediterranean diet, offering significant economic and nutritional advantages (Valiante *et al.*, 2019; Ilari *et al.*, 2021). In Italy alone, the strawberry industry contributes approximately €360 million to the economy, with expectations for market demand to rise further (Pergola *et al.*, 2023). However, the quality of strawberries is highly sensitive to a variety of environmental conditions (Warner *et al.*, 2021), including temperature fluctuations (Khammayom *et al.*, 2022), exposure to artificial lighting (Nadalini *et al.*, 2017), and the presence of pathogens such as fungi, viruses, and bacteria (Abbas *et al.*, 2021). Such fragility makes strawberries particularly suitable for CEA.

This study employs the LCA method to evaluate the potential environmental impacts of a soilless strawberry cultivation system in Maletto (Italy) to identify the most significant environmental hotspots

within this system, providing farmers with insights to make informed decisions for minimizing their environmental impact.

Following the introduction, the subsequent section provides a review of existing literature. Subsequently, the methodology section shows the methodological choices employed for this case study. The ensuing sections illustrate the findings and discussion, culminating in a section offering conclusive remarks.

Literature Review

Research on the environmental effects of traditional soil-based strawberry farming is widespread, with studies conducted in various countries such as Iran (Khoshnevisan *et al.*, 2013; Mousavi *et al.*, 2023), the USA (Clark and Mousavi-Avval, 2022; Parajuli *et al.*, 2022), Germany (Galafton *et al.*, 2023), France (Delahaye *et al.*, 2023), and Italy (Girgenti *et al.*, 2014; Pergola *et al.*, 2023; Valiante *et al.*, 2019). However, investigations into the environmental aspects of soilless strawberry cultivation are not as prevalent.

The limited studies available focused on specific comparisons, like contrasting tunnel-based soil and soilless methods (Ilari *et al.*, 2021) or examined a variety of systems with only a handful being soilless ones (Romero-Gámez and Suárez-Rey, 2020). While these investigations yield important findings, the lack of additional studies focused on soilless strawberries signals the necessity for more comprehensive research on the environmental implications of this farming method relative to conventional soil-based approaches. In addition, the need for this research is highlighted by the conflicting environmental impacts reported in the literature.

For instance, one study (Romero-Gámez and Suárez-Rey, 2020) indicated that high-tech macrotunnel soilless systems have a smaller environmental footprint per ton of strawberries produced than soil-based systems, due to increased yield and lower resource consumption. Conversely, another study (Ilari *et al.*, 2021) pointed out greater environmental impacts associated with soilless tunnel systems in comparison to their soil-based counterparts, citing factors such as substrate use, pesticide application, and fossil fuel dependence. These divergent findings are likely a result of different methodological choices, regional differences, and the distinct objectives of each study.

Thus, the current body of literature presents an opportunity for the expansion of studies into the environmental efficiency of soilless strawberry cultivation, which may offer a sustainable alternative to traditional agricultural practices.

Methodology

LCA is a comprehensive and standardized method for evaluating the environmental effects linked to every stage of a product or system's life cycle (ISO, 2006a; ISO, 2006b).

The goal of this study was to conduct an LCA to assess the potential impacts ascribed to soilless strawberries and identify the most impactful processes in the system.

The research adopted a mass-based functional unit, aligning with the predominant approach in soilless system LCAs, as reported by Licastro *et al.* (2024), thus focusing on 1 kg of harvested strawberries. System

boundaries were defined following a cradle-to-farm gate approach, capturing all relevant inputs and outputs involved in strawberry cultivation. Instead, cut-off criteria included the greenhouse structure and irrigation system. In addition, due to the focus on the production stage, postfarm activities (e.G, packaging of strawberries and transportation to market) were excluded as well. Transportation of inputs to the farm was included. However, wooden crates for plantlings were accounted for solely in the delivery to the farm. Indeed, crop production is considered the process that contributes most to the environmental impacts of farms (Romero-Gámez and Suárez-Rey, 2020). Moreover, due to its generally long lifespan of greenhouse infrastructure is often excluded from the system boundaries (Torres Pineda *et al.*, 2021). When faced with gaps in end-of-life data for agrochemicals and fertilizers packaging materials, it was assumed that these materials are recycled, with the environmental burden transferred to the resultant recycled products, as per the "cut-off" method (Shen *et al.*, 2010).

Primary data, sourced directly from the farmers through interviews and surveys, while secondary data, derived from the Ecoinvent 3.8 database (Ecoinvent, 2024). Data were referred to the production of strawberries in 2023. In instances where specific processes were absent from the database, analogous 'unspecified' processes from Ecoinvent were utilized, particularly for certain agrochemicals and fertilizers. Concerning methods and models to calculate the emission to air and water, methods adapted to the unique context of soilless agriculture, are missing, as highlighted by Llorach-Massana *et al.* (2017). This is due to the distinct chemical and physical characteristics of substrates compared to soil. In addition, it should be noted that by their definition, soil emissions are irrelevant for soilless systems. Nonetheless, in this study emissions to air from synthetic fertilizers were calculated using methods outlined by IPCC (2006) and Zampori & Pant (2019). Similarly, emissions to air from active ingredients in agrochemicals were estimated using Zampori & Pant (2019) with the assumption that 9% of the applied compounds volatilize. Water emissions from fertilizers were determined using IPCC (2006), Zampori & Pant (2019), and Prasuhn (2006). Emissions to water from agrochemicals were calculated assuming that 1% of the applied compound is emitted to water (Zampori & Pant, 2019).

The environmental impact assessment was conducted using SimaPro software version 9.3.0.3 (PRé Sustainability, 2024), applying the CML-IA baseline method (Guinée, 2002) and the IPCC GWP100 (IPCC, 2021) for impact calculation.

System Description

The farm is located in Maletto, Italy (37° 49.4974' N, 14° 50.6408' E) and it is specialized in soilless strawberries cultivation. The soilless greenhouse has two spans, and each span is 16 meters wide and 120 meters long, covering an area of 1200 m^2 and an effective cultivated area of 210 m^2. The greenhouse follows the typical design of the Mediterranean greenhouses that is characterised by steel or iron for the frames and plastic cover for the roof and sides. This greenhouse uses ethylene vinyl acetate (EVA) for covering and has a galvanized steel structure. The crops grow in a coconut fibre substrate in polyethylene bags placed on a channel gutter made of polyvinylchloride (PVC) semi-tubes hold by steel stakes, planted into the ground. The greenhouse contains fourteen rows with a total of 8400 plants, each yielding 1 kg of strawberries per cycle. Indeed, soilless strawberries present higher yields when compared to insoil ones (Romero-Gámez and Suárez-Rey, 2020). The greenhouse requires not heating system, as it is designed to favour natural ventilation. Water is supplied from the local well and collected in tanks were the

fertirrigator mix it with the fertilizers in a dedicated room. A drip irrigation system delivers the fertirrigated water into the substrate bags, then it drains into the PVC gutter. Then the drained fertirrigated water is collected and disposed into groundwater.

Results and Discussion

Figure 1 shows the environmental impacts of the soilless cultivation system.

The results highlight insecticides predominantly affected the abiotic depletion category, contributing 79.32%, with fertilizers following at 18.55%. It should be noted that due to the lack of a specific process for these insecticides an "unspecified" process was used to model these inputs. These results are coherent with those found in Ilari *et al.* (2021) highlighting insecticides as a major contributor to abiotic depletion. This might be justified by the need for frequent treatment to preserve higher yields (Ilari *et al.*, 2021).

Fertilizers exert a widespread impact across multiple impact categories, with contributions ranging from 5.13% in Eutrophication to 64.03% in Terrestrial Ecotoxicity, with an average of 30.60%. These effects are primarily linked to the production of NPK (Nitrogen, Phosphorus, and Potassium) fertilizers. Also, in this case, due to the lack of a specific process for these fertilizers, a generic process was utilized instead. Fertilizers have been found to be the recurrent major hotspot for soilless systems, as noted by several authors (Corcelli *et al.,* 2019; Romero-Gámez and Suárez-Rey, 2020; D'Amico *et al.*, 2023). Several factors contribute to the findings presented. The fertigation cycle of the soilless strawberry is longer compared to conventional soil cultivation, necessitating increased frequency in nutrient and water supplementation. Plus, the growing medium, coconut coir, lacks nutrient content (Munib, 2021), necessitating additional fertilization for plant growth. The absence of a closed-loop system, which could recycle the fertigated water, further exacerbates water and nutrient usage. Instead, the current open-loop system discharges waste directly, leading to environmental repercussions (Rufí-Salís *et al.*, 2020). Despite this, the open-loop system is preferred for its lower installation and operational costs (Licastro *et al.*, 2024). Conversely, closed-loop systems, while costlier upfront, offer long-term benefits for sustainable water and nutrient management, albeit with higher material and energy requirements (Sanjuan-Delmás *et al.*, 2018). Fertilizer impacts can be reduced through various strategies, such as optimizing fertilizer doses to prevent yield loss (Muñoz *et al.*, 2008), substituting with bio-fertilizers (Martin-Gorriz *et al.*, 2021), or replacing inert mediums with nutrient-dense composts (Romero-Gámez *et al.*, 2017). Additionally, farmers might explore advanced cultivation systems like aeroponics, which present innovative solutions (Schmidt Rivera *et al.*, 2023).

The transportation of inputs to the farm was another major hotspot, with the lowest impact being 0.8% in the Abiotic Depletion category and the highest reaching 49.54% in Human Toxicity. Transportation of substrate-filled bags contributed most to these impacts. These findings are largely due to the considerable geographical separation between the substrate's supplier in Northern Italy and the farm's location in Sicily. The majority of these transportation-related impacts are attributed to emissions from EURO3 Lorries, including those associated with the treatment of tire and brake wear. According to some authors (Dorr *et al.*, 2023), transportation of inputs to the farm can be more impactful than delivery to the market.

Highest percentage of electricity consumption was found in Marine Aquatic Ecotoxicity (28.30%); however, it was preceded by fertilizers (29.43%) and packaging (33.58%) in the same impact category.

Emissions to air attributed to the use of fertilizers were the highest in Acidification (59.25%), while emissions to water were prominent in Eutrophication (69.50%).

Finally, the polyethylene bags used for the substrate accounted for an average environmental impact of 17.46%. This impact ranged from as low as 1.07% in the Eutrophication category to as high as 53.70% in Photochemical Oxidation. The extrusion process employed to produce the growing bags was the most impactful process.

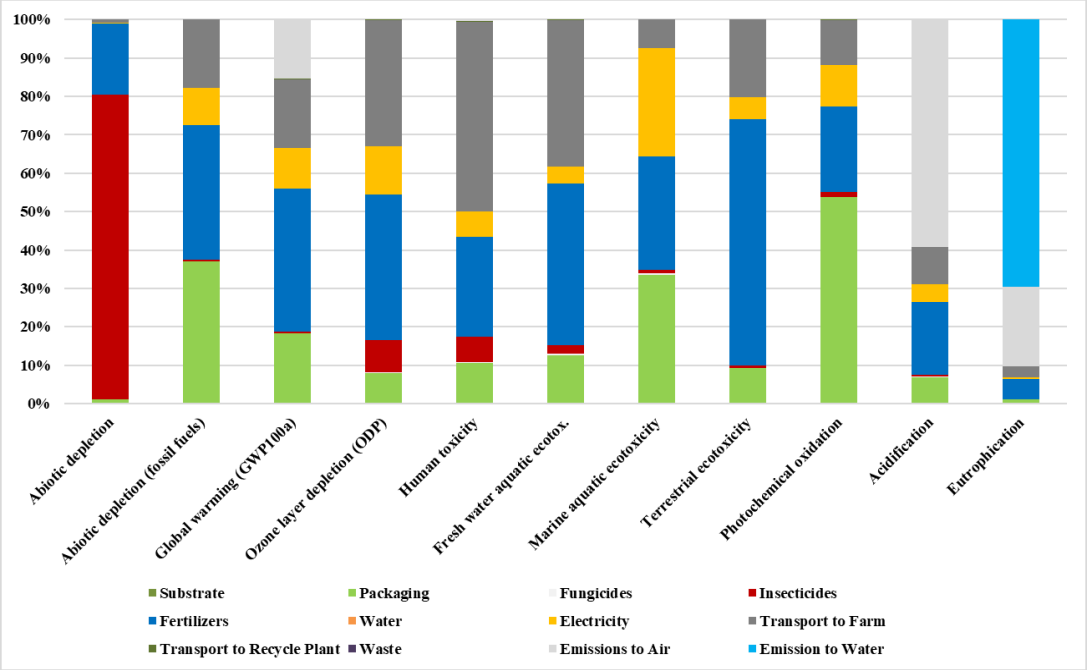

Figure 1. Characterization results of the soilless strawberries system

Considering that agriculture is significantly vulnerable to global warming (Malhi *et al.*, 2021), it is important to give a closer look at the impacts associated with this category. Figure 2 shows the impacts on the soilless systems has on global warming. Indeed, the production of 1 kilogram of soilless strawberries is associated with emissions amounting to approximately to 0.0947 kg CO_2eq. In particular, 37% can be traced back to the manufacturing of fertilizers. Concerning GWP – biogenic, electricity consumption, mainly due to the Italian energy grid mix, is responsible for the 65% of impacts, followed by substrate growing bags (22.83%). Additionally, production of fertilizers also accounts for 80% of GWP-land transformation.

Electricity consumption is often cited as a significant environmental concern in soilless systems, particularly in cooler climates where additional heating is necessary (Maynard *et al.*, 2023; Rothwell *et al.*, 2016). However, the specific system evaluated in this study, located in the Mediterranean's favorable climate, and did not require such inputs for heating. Nonetheless, the heightened electricity demand for prolonged fertigation processes in soilless strawberry farming may still pose environmental challenges. While energy considerations may not be as critical in these cases compared to other studies, the adoption

of renewable energy sources is still advocated to enhance the sustainability of soilless agriculture (Goldstein *et al.*, 2016; Schmidt Rivera *et al.*, 2023).

It should be noted that this study does not include a comparative LCA, however previous comparative research, has shown that soilless strawberries generally exhibit lower environmental impacts in various categories when compared to in-soil systems (see Romero-Gámez and Suárez-Rey, 2020).

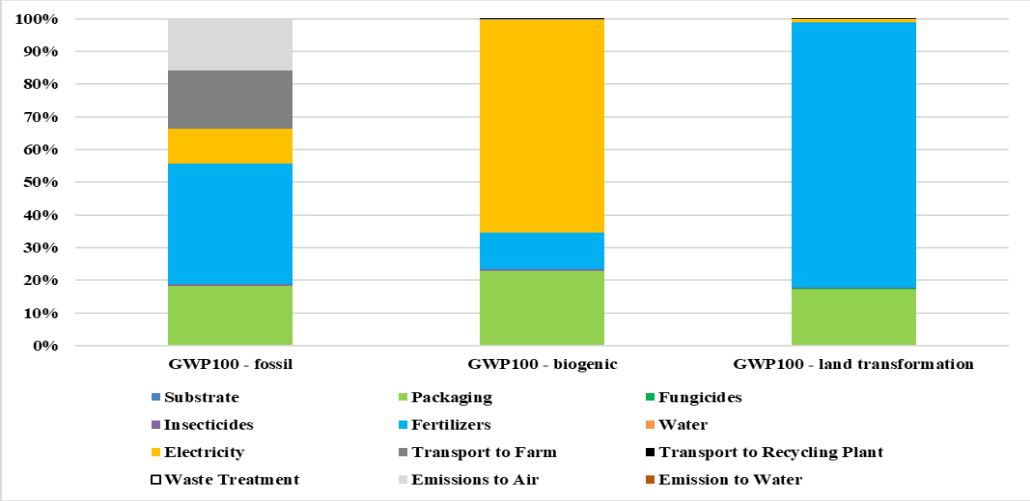

Figure 2. Global Warming Potential of the soilless strawberries system

Conclusion

Strawberries are considered a leading fruit in the context of the mediterranean diet, holding significant economic and nutritional value, but its increasing demand can lead to overexploitation of resources and land, in order to achieve greater yields. This in turn prompts environmental concerns. Soilless systems are seen as a potential solution that could mitigate further impacts by moving the production into more controlled environments. Nonetheless, these systems require holistic approaches, like LCA, in order to assess comprehensively their potential environmental impacts.

This study proposed an LCA of a soilless strawberry cultivation system in Maletto, Italy, providing initial findings on its environmental implications. The study addresses a gap in the literature, as highlighted in the review section, by focusing specifically on the environmental impacts of soilless strawberry production, adding one more study.

These findings revealed that the main environmental hotspots in this system are fertilizers, transportation of the substrate and substrate polyethylene bags. Insecticides predominantly affected the abiotic depletion category, while fertilizers had widespread impacts across multiple categories, particularly in terrestrial ecotoxicity. The transportation of inputs, especially the substrate bags, emerged as a significant contributor to environmental impacts, largely due to the geographical distance between suppliers and the farm. Additionally, the polyethylene bags used for the substrate showed notable impacts, particularly in the photochemical oxidation category.

While such systems offer potential benefits like higher yields, they also present challenges, particularly in terms of fertilizer use and transportation impacts. The study highlights the need for optimizing fertilizer application, exploring alternative substrates, and considering closed-loop systems for more sustainable nutrient and water management.

The global warming potential analysis further emphasizes the importance of addressing fertilizer production and electricity consumption in improving the environmental performance of soilless systems. While the Mediterranean climate mitigated some energy-related impacts, the adoption of renewable energy sources could further enhance sustainability.

This research contributes to the growing body of knowledge on sustainable agricultural practices, aligning with multiple Sustainable Development Goals. It provides farmers, policymakers, and researchers with information for developing and implementing more environmentally sustainable farming techniques.
However, it is crucial to acknowledge the limitations of this study. The models and methods used for calculating emissions in soilless systems are lacking, and their development and subsequent application could lead to different results in future studies. The unique physical and chemical properties of substrates, compared to soil, necessitate the development of tailored emission calculation methods. Additionally, this study excluded the greenhouse structure and irrigation system from the analysis, and their inclusion could alter the outcomes. Furthermore, the choice of impact assessment methods and functional units can significantly influence results.

Moving forward, further studies across diverse geographical and climatic contexts will be essential to fully understand and optimize the potential of soilless cultivation systems. Additionally, exploring innovative solutions such as bio-fertilizers, nutrient-filled composts, and advanced systems like aeroponics could pave the way for more sustainable CEA practices. In addition, future studies can focus on the whole life cycle of the strawberry, including the greenhouse structure as well as the irrigation system. Moreover, since this study focused on the environmental aspects of these systems, other areas of research could include the assessment of their economic cost via Life Cycle Costing (LCC), as well as the assessment of the social impacts of such systems, using a Social Life Cycle Assessment (S-LCA). Indeed, soilless systems are suitable for urban areas and can be implemented in degraded areas to empower locals by creating new economic activities. Furthermore, models and methods to compute emissions in soilless systems are missing, hence another research area could be focused on development and application of models adapted to these systems. Future research should also consider conducting sensitivity analyses on various parameters, such as yield and emission calculation models, to provide a more comprehensive understanding of soilless systems. Adopting multiple functional units in future studies could also offer a more complete perspective on the environmental impacts of these systems.

In conclusion, while soilless strawberry cultivation shows promise in addressing some environmental concerns associated with traditional agriculture, it also presents its own set of challenges. Balancing technological advancements with ecological considerations will be crucial as we strive to meet growing global food demands while minimizing environmental impacts.

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How Can Design Discipline Contribute to the Sustainable Food System Transformation? A Review of Research Projects in the Italian Context

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Abstract

The road for the food system toward a more sustainable scenario requires consideration of all the stages of the food chain, with cooperation from all the disciplines to which the design can contribute. A literature review is conducted to individuate research projects, limited to the Italian context, in the design field for the agri-food sector, where outputs can be diverse from objects. The goal is to understand how the design field can argue for a more sustainable scenario for the food system. The results give interesting insights into practices and actions just applied and reveal that most of them integrate reasoning over the food system's sustainability. Afterward, the results of the review are applied to reflect in a specific research context around the production of two typical Italian products in two different territories of the Veneto region: the hills at the foot of the mountains Dolomiti for Prosecco wine and a part of the big plain Pianura Padana on the banks of river Adige for Lusia salad. This paper gives insights for a reflection on the design for a sustainable food system and a territorial development that respects the planetary boundaries, ecological common goods, and social conditions of citizens.

Introduction

According to Clark *et al.* (2020), global food system emissions could preclude the targets set to prevent climate change disasters. Indeed, the entire food chain creates 26% of anthropogenic GHG emissions, where food production is the most impactful stage of the chain (Poore & Nemecek, 2018). The road for the food system transformation towards a more sustainable scenario, therefore, requires consideration of all the stages of the food chain, with great effort and cooperation from all the disciplines to which the design can contribute. A general overview of the contribution of design discipline in the food field has been defined food design (Massari, 2017; Bassi, 2015). Thanks to the strict relationship among food and the territory, also *design for territories* (Parente & Sedini, 2017) subfield can contribute.

This paper focuses on the research in the design field for the agri-food sector, providing a literature review of the main research projects carried out in Italy in the last 10 years, where sometimes the outputs are not only the design of an artefact, which is the traditional design output. The goal is to understand how the design field can argue for a more sustainable scenario for the food system, thanks to the many diverse outputs that the research in this discipline can provide.

Finally, in the last chapter there is a reflection on the contribution of design in a specific research scenario. The review's results are indeed applied to two different territories of the Veneto region, where a group of multidisciplinary researchers is working: Vittorio Veneto municipality placed in the hills at the foot of the mountains Dolomiti prealpi where Prosecco wine is produced; Lusia municipality, a part of the big

plain Pianura Padana on the banks of river Adige where Lusia salad is cultivated. The location of the two case studies is related to mountain (pre-alps) and river contexts, core topics of the conference, which can potentially contribute to the discussion over a more sustainable future for these territories. In conclusion, this paper gives insights into reflecting on the design for a sustainable food system and territorial development that respects the biophysical thresholds of planetary boundaries, ecological common goods, and citizens' social conditions.

SDGs involved: 2.4; 6.3; 12.2, 12.3, 12.5, 12.8; 13.3; 14.1; 15.1, 15.3.

This study is part of a broader research project that involves a group of multidisciplinary researchers at Università Iuav di Venezia, conducted in 2023-2024.

Literature Review

This paragraph presents the current literature situation on the relationship between food, design, and sustainability.

Design and Food

The contribution of design discipline in the food field has been defined *food design* by some authors. Massari (2017) defined the differences between food studies and food design studies as: "*studies on agri-food production (food studies) and design studies relating to food (food design studies) are two relatively new areas of research*" (Massari, 2017). This new area of design, having today also a dedicated journal, the International Journal of Food Design, has become an educational topic, defined food design education (Massari, 2017). Bassi (2015), in his book on the history of design of food as a product in Italy entitled "Food Design", reminded that in the Italian context, the Italian designers internationally famous haven't forgotten to work in the food sector, an important economic sector and an important part of the national culture. Designers have worked on new shapes of pasta, famous packaging, advertising (Carosello), cutlery and crockeries, and more. He divided food design into: design with food - related to the way to prepare dishes -; design for food - the modalities of consumption and service -; design of food - as a design product - (Bassi, 2015).

Food is also an important topic dealt by other disciplines as planning. Indeed, the relationship among food and space is strong (Lazzeroni *et al.*, 2023) and emerged several times in the food system planner (Soma & Wakefield, 2011).

Thanks to the strict relationship between food and the territory, also design for territories (Parente & Sedini, 2017) design subfield can contribute to the reasoning about the relationship between food and design. Parente & Sedini (2017) recognized the division among: design in the territory to enhance local cultural products, or resources related to environmental, historical and cultural heritage - works on city, place, country fruition -; design of the territory insists on products, communication systems and services related to local organisations - works on local, territorial, national identity -; design for territories, a field of study considering the territory as a design object - works on design and crafts, design and local

productive districts, made in -(Parente & Sedini, 2017). They are "*three approaches that gradually expand the observation from the territory as a context of design, to an object of intervention and then to a relational system*" (Parente & Sedini, 2017).

Subsequently, another Italian scholar working on the food and the territory is Catania (2011 a) who identified the role of design in the valorization of the local production and of innovation of the territorial capital. One of her case studies is the project on the local food system in Sicily (Catania, 2011 b). Catania (2017 a, p.84) strictly related food and territory "*food tells the story of the territory and its products, the rituals and the symbols of the gastronomic tradition. Today, food in a territory also becomes an expression of values to be promoted and design can bring new opportunities. The design culture, using its tools, starts a virtuous cycle between product and territory and can carry out the regeneration of the territory and the sustainable development of economic activities at local level*". In her works the relation between food, design and sustainability appeared.

Food, Design and Sustainability

Due to the high impact of the food systems on the planetaries boundaries and consequently climate change (Nature Food, 2023), there is the need to restructure food systems towards sustainability. In the European context, this need is addressed by the Farm to Fork strategy, with the aim to "*designing a fair, healthy and environmentally-friendly food system*" (EC, 2020), where all the stages of the food chain should have a neutral or positive climate and environmental impact (EC, 2020). At the world level, in the Sustainable Development Goals set by United Nations, food is related to two SDGs: SDG 2 "Zero Hunger", and in the third target of SDG 12, "Responsible consumption and production" setting target for halving global per capita food waste and food losses by 2030.

Design in general is questioning its role, in particular in the research area of design for sustainability, developing from end-of-life considerations to product design for sustainability and circularity, and product-service-systems (Ceschin & Gaziulusoy, 2016). Circular design is also another set of strategies to design for the circular economy.

Additionally, contributions over food design also discuss the need for sustainability in this sector. The Ellen MacArthur Foundation, known for circular economy studies, defines the circular design for food as: '*..to design for positive consumer, farmer, economic, and environmental outcomes, the principles of the circular economy can be applied to the way we design food…*(...)*..In order to maximise benefits in the food system, circular economy principles should be applied across all dimensions of food design, from product concept, through ingredient selection and sourcing, to packaging...*" (Ellen MacArthur Foundation, 2021). Moreover, it identifies four circular design opportunities for food: diverse - diversity of animal and plant varieties and species as ingredients -; lower impact - 'quick win' ingredient that have fewer negative impacts; upcycled - transforming inedible food byproducts into new ingredients; regeneratively produced - regeneratively produced ingredients. Also, Fassio identifies that food can play an important role in the transition towards a circular economic paradigm. First, Fassio & Tecco (2018) in their book analysed several implemented cases of circular economy for food. Moreover, Fassio (2021), in defining a conceptual framework for circular design in the food system, highlights the 3 C's - Capital, Cyclicality and Co-evolution

- to offer a holistic vision of the food system's role. Capital stands for preservation and regeneration at a local level of natural capital, to protect the cultural capital, to produce a distributed economic capital; cyclicality for thinking in regenerative terms; co-evolution for the mutualistic symbiosis that is possible to find in nature. Catania (2011 a) also insisted on the importance of working with the local actors and for new sustainable production systems, citing Bistagnino (2011) who proposed the use of a systemic approach in design, theorising the Systemic Design (SD) to obtain new sustainable production systems working on the connection between output and input of production processes, eliminating wastes, as happen in nature.

Methodology

To understand how the design field can argue for a more sustainable scenario for the food system, thanks to many diverse project outputs that the research in the design field can provide, first, a literature review was conducted to discover these research projects. The review started and was limited to the Italian context for few reasons: time constraints (1 year research); agri-food in Italy is the most important economic sector - 580 billion euros in 2022 (Unioncamere, 2023) with 327 traditional registered products (MASAF, 2024); Italy is the home and the country of work of the authors so it was possible to discover more contributions also written in Italian. The review included research projects performed by Italian designers on food. The contributions were mainly found in the library for Italian books, and in the proceedings of the Italian annual assembly of the Italian Society of Design (SID). It was also used the working experience of the authors. From the first contributions found, a snowball process was applied to include more works related to these authors.

The review results help reflect on the contribution of design in this topic, giving insights for new perspectives on the design for a sustainable food system and toward a territorial development that respects biophysical thresholds of the planetary boundaries, ecological common goods, and social conditions of citizens. Afterward, the results are applied in a specific research scenario, where the group of six multidisciplinary researchers of Università Iuav di Venezia, where authors are included, is working. The disciplines involved are: planning design, product design, economy and rural estimate, economic anthropology, gastronomic sciences. Precisely, the research is based on the production of two typical Italian products in two different territories of the Veneto region, where the university is located. These territories have been primarily dedicated to these products, overshadowing other activities, creating an increase in the local economy, but also by increasing environmental impacts. They are: the hills at the foot of the mountains Dolomiti prealpi where Prosecco wine is produced - with a focus on Vittorio Veneto municipality -, and a part of the big plain Pianura Padana on the banks of river Adige - Lusia municipality - where Lusia salad is cultivated.

Results and Discussion

Literature Review Results

The review finds 34 contributions about the category of design research projects, the one listed in table 1. The review moreover discovers some theoretical contributions, which are highlighted in tab. 2, and educational programs, which are highlighted in tab 3.

Table 1. Design research projects found and considered in the review

No	Reference	Research Period	Project Leader	Geographical Location of Project	Part of the Food Value Chain Involved	Main Agrifood Sector Involved	Impact on Sustainability (Environmental, Social, Economic)
1	Fassio et al., (2022)	2022	UNISG	Piedmont region (IT)	Food production, transformation, and supply	Wine, dairy, cheese, rice, water, and bovine beef	Environmental mainly - food waste and byproducts management
2	Fiore et al. (2020)	2020	Politecnico di Torino	Piedmont region (IT)	Food production (by-products)	Wine	Environmental - management of Piedmontese by-products (rice and wine)
3	Barbero & Fiore (2015)	2013	Politecnico di Torino	Torino city (IT)	Food consumption (by-products)	Coffee	Use of by-products for different businesses, particularly coffee grounds
4	Barbero & Tamborini (2012)	2007-2013	Politecnico di Torino	Cuneo, Piedmont region (IT)	Food production (by-products), distribution, packaging design	Beans	Impact on land conservation, packaging production, and optimization of material and energy flows
5	Barbero & Battistoni (2016)	2016	Politecnico di Torino	France	Food processing (by-products)	Biscuit	Sustainable production, changes in supply chains
6	Battistoni et al. (2020)	2020	Politecnico di Torino	Piedmont region (IT)	Food processing (by-products)	Hazelnut	Analysis of the transformation process and use of by-products
7	Bozzola et al. (2017)	2015	Politecnico di Torino	Italy	Food service consumption (food waste)	General	Action on leftovers, social responsibility for food waste reduction
8	Bozzola & Dal Palù (2018)	2015	Politecnico di Torino	Turin, Italy	Food transformation (food waste)	Fruits and vegetables	Food waste reduction, social inclusion, and education projects
9	Campagnaro & Ceraolo (2017)	2017	Politecnico di Torino	Turin, Italy	Food transformation (food waste)	Fruits and vegetables	Food waste reduction, social inclusion, and education projects
10	Campagnaro et al. (2020)	2020	Politecnico di Torino	Turin, Italy	Food waste awareness-raising	General	Awareness-raising on food waste with a view to circular economy and social cohesion

No	Reference	Research Period	Project Leader	Geographical Location of Project	Part of the Food Value Chain Involved	Main Agrifood Sector Involved	Impact on Sustainability (Environmental, Social, Economic)
11	Campagnaro et al. (2023)	2023	Politecnico di Torino	Turin, Italy	Food distribution network	Generic	Social sustainability through inclusion, tackling food access, and food capability building
12	Campagnaro & Bosso (2024)	2024	Politecnico di Torino	Turin, Italy	Food cooking	Generic	Social impact through food access and inclusion
13	Savina et al. (2018)	2018	Politecnico di Torino	Turin, Italy	Food production (food procurement)	Generic	Impact on public health - decrease illness through improved public food procurement
14	Kloeckl et al. (2010)	2009-2010	Università Iuav di Venezia	Veneto region (IT)	Food distribution and packaging	Salad	Environmental - use of nanotechnologies to create high-performance materials
15	Battistoni (2023)	2022-2024	Università Iuav di Venezia	National	Food service (professional kitchens)	Generic	Environmental - saving water in professional kitchens
16	Fagnoni (2018)	2018	Università Iuav di Genova	National	Tourism (wine)	Generic	Not specified
17	Trebbi (2023)	2023	Sapienza University of Rome	Rome, Italy	Food packaging	Biomaterials	Environmental - making biomaterials through everyday products and implementing symbiotic processes
18	Di Bucchia et al. (2018)	2014-2015	Università d'Annunzio di Chieti-Pescara	Pescara, Italy	Food consumption (storage, preparation, consumption)	Generic	Social - design for industrial products for food and beverages
19	Galbiati et al. (2017)	2014-2015	Politecnico di Milano	National	Food waste from consumption	Generic	Social - social communication campaign
20	Carraro et al. (2023)	n.d.	Politecnico di Milano	Reggio Emilia, Italy	Food preparation (donation)	Generic	Economic - accessibility to healthy and sustainable food systems for all

No	Reference	Research Period	Project Leader	Geographical Location of Project	Part of the Food Value Chain Involved	Main Agrifood Sector Involved	Impact on Sustainability (Environmental, Social, Economic)
21	Bianchi et al. (2023)	2019-2022	Politecnico di Milano	Milano, Italy	Food markets (municipal markets)	Fruits, vegetables, meat	Environmental and economic - food markets as circular digital hubs
22	Cioffi et al. (2021)	2021	Università degli Studi di Campania Luigi Vanvitelli	Campania region, Italy	Food waste management	Wine	Environmental and economic - recovery, reuse, and valorization of residues and by-products
23	Marti et al. (2023)	n.a.	Università di Siena and Pisa	National	Supply chain (fish)	Generic	Not explicit
24	Filippi et al. (2022)	2022	Università di Firenze	Raggiolo (Arezzo), Italy	Production	Generic	Not explicit
25	Morone & Parlato (2019)	n.a.	Università di Napoli	Napoli, Italy	Consumption	Generic	Not explicit
26	Formia et al. (2024)	n.a.	Università di Bologna	International	Food awareness	Generic	Social and environmental - responsible innovation
27	Manfra (2022)	2022	Università di Camerino	National	Agriculture (water use)	Generic	Environmental - responsible water use in agriculture
28	Manfra (2023)	n.a.	Università di Camerino	Marche and Abruzzo regions (IT)	Agroecology	Agroecology	Agroecology
29	Catania et al. (2011)	n.a.	Università di Palermo	Sicily, Italy	Packaging (typical product)	Generic	Environmental - eco-design for typical products and consumption
30	Catania et al. (2017)	n.a.	Università di Palermo	Sicily, Italy	Packaging (labeling)	Olives	Not explicit
31	Canina & Monestier (2023)	n.a.	Politecnico di Milano	National	Generic (sustainable food practices)	Generic	Environmental - sustainable food practices and natural-based coatings
32	Piselli et al. (2016)	n.a.	Politecnico di Milano	National	Packaging	Paper	Environmental - natural-based coatings for packaging

Table 2. Theoretical contributions found during the review

no	Reference	Affiliation	Part of the Value Chain Involved	Impact on Sustainability
1	Bassi (2015)	Università Iuav di Venezia	Food consumption	No
2	Catania (2017)	Università di Palermo	Food identity	Environmental – partially
3	Catania (2011)	Università di Palermo	General	Generic
4	Fassio (2021)	UNISG	General	Yes – Conceptual framework for circular design in the food system
5	Fassio & Tecco (2018)	UNISG & Università di Torino	General	Yes – Circularity in the food system
6	Massari et al. (2023)	University of Pisa	Food transformation and supply	ICT tools for monitoring ecological footprint

Table 3. Educational programs found during the review

no	Name	Typology	Institution	Language	Impact on Environmental Sustainability	Reference
1	Design sostenibile per il sistema alimentare	Bachelor degree	Università di Parma	Italian	Yes, partially	https://corsi.unipr.it/it/cdl-dssa
2	Design for Food – Innovation for Circularity	Master	Politecnico di Milano	English	Yes	Milano ign.net/en/formazioinnovationne/business-design/master-circularity design-for-food/ future
3	Polito Food Design Lab	Research lab	Politecnico di Torino	Italian	Yes, partially	Ceraolo & Passaro (2019)
4	Gastronomic Science (including Design)	University	Università di Scienze Gastronomiche	English	Yes, partially	https://www.unisg.i

Regarding packaging, Bozzola *et al.* (2017) and Bozzola & Dal Palù (2018), through a didactic experience on designing products for leftovers pack and transport, the so-called “doggy-bags”, they focus on increasing meaningfulness and value perception of food resources, raising public awareness on the food waste reduction importance in an environmental, ethical, social, cultural and economic context”. In the project Memo by Veneziano (2018) it was designed a food packaging, a launch box, linked to a social project on the willingness to increase awareness on the culinary tradition of Napoli, which involved a co-design phase with many local actors. Veneziano (2018) insisted on the need to a moment of "listening" during the reading and interpretation phase of the territory. On the same topic, with a different scope, also Kloeckl *et al.* (2010) worked) in a design experience over designing for agriculture, a collaboration among Università Iuav di Venezia and Coldiretti (Italy's largest agricultural association) in the Veneto

Region. The packaging has become a technical device to conserve the salad, a barrier from external atmosphere, a way to measure the food portion, the document of a production history, and thanks to an rfid tag, it is also a way to trace the food supply chain (Kloeckl *et al.*, 2010). The project by Piselli *et al.* (2016) is on packaging, but it is more on technical aspects, to find a sustainable alternative to recyclability and compostability for greasy food, designing new prototypes using polysaccharides-based coatings.

Among the many collected works, a few were based on the exploration of processes and system to individuate by-products and explore potential use of it. Cioffi *et al.* (2021) works on the management of residues and by-products, through recovery, reuse, and valorisation of wine industry. The following projects explore how to connect different productions systems through the by-products, using SD, as evidenced by the work on hazelnut by Battistoni *et al.* (2020), beans (Barbero & Tamborrini, 2012), coffee (Barbero & Fiore, 2015), biscuits (Barbero & Battistoni, 2016), in Politecnico Torino with the lead of Barbero and Tamborrini. In the same institution emerged the work by Campagnaro & Ceraolo (2017), Campagnaro, Passaro & Stabellini (2020), Ceraolo & Passaro (2020) to fight food waste towards a new social food chain with multiple experience as The Egg of Columbus workshop and The Egg of Columbus Lab. In this context food waste is elaborated for creating new food. This group lead by Campagnaro have also worked at the Alimenta project, a design-led systemic action against homelessness-related food poverty (Campagnaro *et al.*, 2023) working more on the social sustainability through inclusion tackling food network and food capability building, and also this experience has become a didactic experience on design for social impact (Campagnaro & Bosso, 2024). In these experiences, food is treated as a design material.

Further to this, two projects have worked on the intersection among different food value chain, in Piedmont Region. Fiore *et al.* (2020), with the Innovaecofood project on rice and wine value chains, and the work of Fassio *et al.* (2022) on wine, dairy and cheese, rice, water, and bovine beef. Also, the work by Trebbi (2023), analyses the by-products of brewery, wine producer, juice bar and a coffee bar to evidence the creation of multiple new products and also a diffuse micro-factory, for circular distributed production system for microbial nanocellulose.

Some projects worked on specific topics such as water use, agroecology or health. Concerning water, Battistoni (2023)'s work focus on the relationship of design and sustainability for the food service focuses on food transformation in professional kitchens, analyses the resources involved in addition to the food, and concentrates on water for food—the food-water nexus—to understand how to design professional equipment for the circular economy scenario. Instead, the project by Galbiati (2017) on the realisation of an 'unconventional' social communication campaign worked on the consumption and waste of water. In this context, the role of design was used as a tool to interconnect different cultural, linguistic and technical skills because it can address a topic under different disciplines and communicate it in an original way. Also, Manfra (2022) worked on water, claiming for a responsible water use in agriculture, bringing examples and highlighting the need for designers to offer sensitive, breaking and radical contributions against the unsustainable logic. Manfra (2023) worked on agroecology to create positive connections between small farms, land resources and communities by introducing innovations in agricultural practices that do not depend on the surrounding socio-economic and cultural conditions. In this research, design plays a facilitating role in combining organisations and training groups that come together spontaneously, combining their ways of working into a single integrated process. Regarding health, the research project

by Canina and Monestier (2023) aims to imagine new design processes to support a more sustainable food system than the current model, following the 'Design Futures' approach, focusing on a case study on the relationship between food and health that shows the customisation of food according to lifestyle, as witnessed by meal replacements and bioactive diets. Also, in this case is discussed the potential applications of digital technologies to the food system. Savina (2018) on the impact of food production on public health, developed systemic strategies for a diffused and transversal prevention plan.

Following this, some projects worked on the communication part of projects, such as Catania (2017b) designing a label of packaging that can tell the quality of the product, the company philosophy, and the territorial peculiarities. Morone & Parlato (2019), analysed how food in Napoli, and the communication around it, is an identity that can create exploitation and belonging. About food as territorial identity, Fagnoni (2018) highlighted that in the wine sector, architecture and design create markers, and the cellars and tasting places have the role of territorial-hub to promote territorial activities and also tourism. A communication project is also the community map by Filippi *et al.* (2021), a particular tool drawn up and constantly updated by the local population, who collects the social and cultural aspects of a particular place. It is a project resource to preserve and pass on knowledge, traditions and values, and a reservoir of ideas for new forms of planning, development and innovation. The project by Galbiati (2017), as seen above, conjugates communication and education.

Several projects worked on the inclusion of the digitalization part in projects. Bianchini & Maffei (2023) consider food markets as circular digital hubs, worked on a Food Market 4.0 designing and prototyping three product-service system solutions focused on waste prevention, digitisation of markets (wi-fi, tracking, data management and analysis, smart checkouts and Iot solutions) and to encourage interaction between markets and neighbourhoods (from food apps to home delivery). Also, Marti *et al.* (2023), focuses on the potential of design enabled by digital technologies, highlighting the need to educate future designers to adopt a systemic perspective, designing new solutions involving stakeholders, following prototyping techniques, evaluation methods and field testing.

Formia *et al.* (2021) uses design as an instrument in the service of responsible nutrition, designing food products, packaging and consumption systems to meet the digital and green transitions, working with South American universities.

Projects worked also on the social sustainability of projects as the project by Di Bucchianico (2017) that worked on Design for All to identify and develop new ideas for 'inclusive' industrial products for the storage, preparation or consumption of food and beverages. In a discussion of social justice and how it is affected by food, we must reconsider the fundamental right to accessibility to healthy and sustainable food systems for all. This topic was discussed by the authors Carraro *et al.* (2023), analysing in depth the issue of food donation to identify design opportunities and developed ideas to improve the circularity of the food system in specific territories. The co-design process was essential.

Contribution of Design for a Sustainable Food System and a Sustainable Territorial Development

According to this review it is possible to understand that the design in the last years have moved to the pure design of artefacts, but it is enlarging its scope with projects that involve many other aspects. In the

food sector researches on design are considering by-products used as resources for new products, the design of local and circular food systems, actions for education on food systems, the integration of digital technologies for a sustainable transformations, the use of a participatory design approach, the attention of social sustainability working on the redistribution of food surplus, actions to reduce homeless food poverty and social eating activities. Many of them included reflections over food system's sustainability and circularity.

In particular, according to these research projects, design can intervene in:

- promotion of territorial heritage and related food products (design for territory);
- sustainable and communicative packaging;
- design with food as a “design material”, for valorization of agri-food by-products used as resources for new products creating circular local production system;
- understanding the local food system to act for a new system more sustainable (ex: act on the use of water for food production or cooking) thanks also to data visualisations;
- integration of digital innovations for sustainable transformations;
- communication campaigns, to reduce food waste or create a food education;
- Workshop to co-design processes, stimulate innovation processes and participatory design in food experience.

Specific Application to two Veneto Region Territories

The research especially wants to understand the contribution of design in a specific research scenario where a group of multidisciplinary researchers is working. This context is the geographical area characterising the production of two typical Italian products in two different territories of the Veneto region. These territories have been primarily dedicated to these products, overshadowing other activities and also creating environmental impacts. We are referring to the hills where Prosecco wine is produced - a focus on the municipality of Vittorio Veneto -, and a part of the big plain Pianura
Padana on the banks of river Adige - Lusia municipality - where Lusia salad is cultivated

Vittorio Veneto (TV) and Prosecco area

Vittorio Veneto is a city of around 27.000 inhabitants in Treviso province in Veneto region (IT) located in the hills at the foot of the mountains Dolomiti prealps. For the 53, 92% the territory is covered by wooded areas, 28.51% by agricultural surfaces, 16.42% urbanised areas, 1.15%rivers, streams and lakes. As can be seen from fig. 1, Vittorio Veneto is included, to the south, in the Controlled and Guaranteed

Designation of Origin of Prosecco di Conegliano and Valdobbiadene, the "historic" production area of Prosecco, and since 2019, the Municipality has been part of the UNESCO site "The Hills of Prosecco of Conegliano and Valdobbiadene", as core, buffer and commitment zone. Viticulture plays a particularly significant role here, so much so that 36.38% of the agricultural territory is covered, in 2020, by vineyards, the second most important use of agricultural land after herbaceous covers. In the wake of the international economic success of Prosecco (currently the most exported Italian wine in the world), Vittorio Veneto has become, in recent years, one of the municipalities of the Conegliano Valdobbiadene DOCG which has recorded the greatest increase in vineyard surface area, with important consequences

in terms of landscape-territorial modifications (Basso, 2019). If in 2015, for example, the vineyard surface amounted to approximately 915.91 hectares, it increased by 17.29% between 2015 and 2020 (see fig. 2, left). Of the 196.74 hectares of new vineyard planted in the five-year period, 68.96% replaced land previously used for arable land, 20.10% woods and 4.29% meadows.

In the DOCG Prosecco territory, although predominantly made up of vineyards, also hosts other products that make up the local gastronomy. In these hills, in fact, a historical and dedicated production is attributed to the cultivation of olive trees, from which an excellent quality extra virgin olive oil is obtained. Additionally, chestnut trees grow on the hills, and chestnuts have a PGI label Throughout the Pedemontana trevigiana, dairy products and animal-based preparations are also abundant as grilled meat and preparations such as braised meats always accompanied by polenta. Along them there are also appreciated cheeses, all certified PDO and this list is further enriched by a long tradition of herbs, snails, and mushrooms.The basket of products mentioned above confirms the fact that these territories can offer different types of production and that in addition to Prosecco, many other local and indigenous wines are drunk. (Proloco Vittorio Veneto, n.a.)

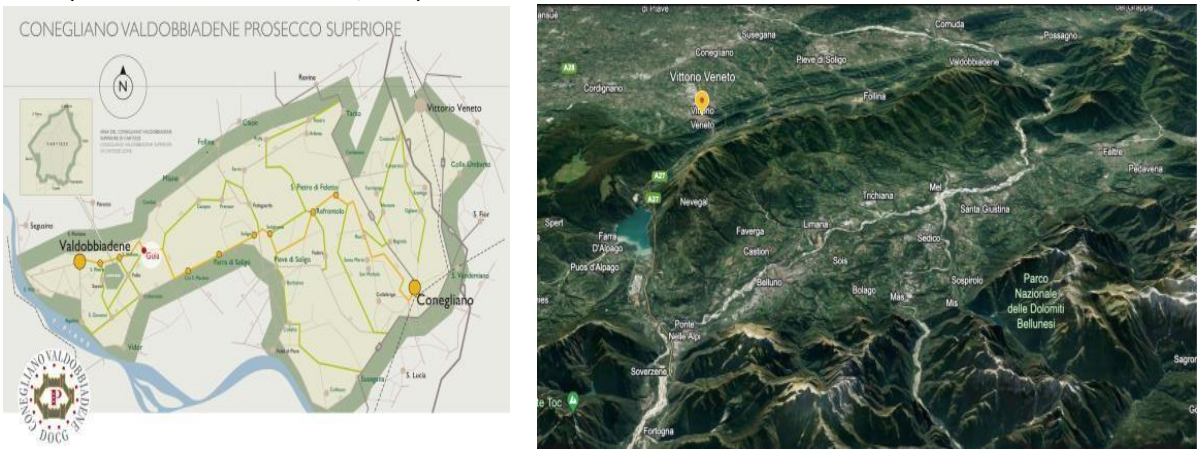

Figure 1. The area of Prosecco. On the left the area of the Prosecco Conegliano Valdobbiadene DOCG. On the right the area seen from google earth

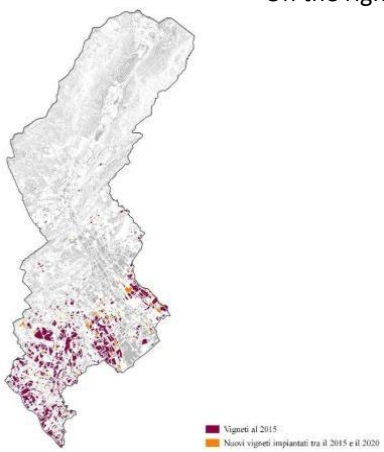

Figure 2. Vittorio Veneto municipality. On the left the evolution of the vineyard surface between 2015 and 2020. Elaboration by Matteo Basso on AVEPA data. On the right a collage of food and beverage products in the area.

In this context, the design can contribute to create a coordinate image of the Prosecco area, including also the Vittorio Veneto area which many times resulted on the corner of the map (see fig. 1, left). Moreover, it is possible to work on the promotion of the long territorial heritage (design for territory) and also to the other food products that belong to the heritage, as the products of the woods, creating also new maps as in the work by Filippi *et al.* (2021). In addition, using a SD approach, it is possible to visualise and understand the local food system, to individuate the nodes and intervention points on where to act for a new system that is more sustainable. Individuating, for example, the main waste stream produced in the area, the actors and stakeholders that are already existing and the ones that are needed for a different management. In addition, a SD approach can also help to understand the environmental impact of the Prosecco production on the natural ecosystem as the pollution of air and water. Once the new resources on where to work are defined, there is the possibility to work to create new foods or the new products (as created from by-products) and then promote the new products, working on the packaging and the communication. This can help to contribute to move the attention to not only to the product Prosecco.

Lusia (RO)

Since the 1930s in Lusia there were the pedoclimatic conditions suitable for the production of vegetables and salads, also due to the presence of the Adige River which crosses the territory. “Lusia Salad”, with a hundred-year history, has the European record of being the only one protected by the I.G.P. mark. (Protected Geographical Indication) obtained in 2009. Its quality derives mainly from its geographical production area and the particular combination of some pedoclimatic factors of the area, such as atmospheric humidity, the presence of constant water along the canals and the presence of loose fertile soils rich in mineral salts, which give it a perceptible flavour. In fact, the soil is characterised by a superficial layer of sand brought by numerous floods (Adige) and with a mixed texture towards the hinterland, with constant humidity and permeability due to the high-water table and artificial canals. In an area of 1.760 ha, the arable land in irrigated areas is around 1.310 ha. The fields for salad are about 110 ha and the open field for other vegetables are around 300 ha. There is also production of soy, wheat, corn, barley. Today fruit and vegetable cultivation is the dominant activity with a total of approximately 150 hectares of greenhouses.

Figure 3. The Lusia area. Left: land use of the area. In light green the fields dedicated to the arable land. Elaboration of Alberto Bonora. Right: picture of the greenhouses and of the Lusia salad

Also, in this context, the design can contribute to both the communication of the principal product, for a coordinate image of the area, and also to give a window to other food products that are possible to produce in this area thanks to the specific characteristics. The SD approach can help to visualise and understand the local food system, to individuate the nodes and intervention points on where to act for a new system that is more sustainable, highlighting resources consumption and by-products produced, acting as in the project of beans cultivation by Barbero and Tamborrini (2012). It is possible to work both with the producers, but also in the transformation phase, where the salad is cleaned or other vegetables and fruits are transformed, and in the food consumption. To increase the traceability with the use of packaging, it is possible to implement a project like the one by Kloeckl *et al.* (2010). For a more responsible water management in this context, it is possible also to implement some of the examples that Manfra (2022) highlighted in his contribution over a more responsible use of water in agriculture, or using the framework by Battistoni (2023) to work on food preparation (e.g. vegetables washing) both in food service and in domestic contexts.

Conclusion

This paper, thanks to the review of Italian research projects, gives insights for a reflection on the design for a sustainable food system and a territorial development that respects biophysical thresholds of the planetary boundaries, ecological common goods, and social conditions of citizens. Moreover, design can help to design for the valorization of the local production and of innovation of the territorial capital, enhancing local culture, thanks to artefacts and communication practices.

In this scenario, the designer can apply different skills that can be acquired over the original contribution on product development, graphics and communication. This professional figure can be involved in many parts of the food system to enable the system transformation. In particular, this professional can have the tools to assess circular economy opportunities at the systems level, envisioning future worlds and using a tangible vision thanks to artefacts. In addition, from being explorers in the preliminary research and framing phase, the designer then can play the role of facilitators and mediators between actors, conducting co-design processes for innovation (product, process, service) and guiding the collective creativity.

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Posters

Submission ID 96

Extent and Food Crop Production Potential of Abandoned Farmland in China

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Abstract

The impact on food production should be the top concern of China's farmland abandonment. This study took into account both inter-annual and seasonal farmland abandonment in China and assessed their extents and food production potentials by combining land use data, cropping intensity data, statistical data, and the China-AEZ model. Results showed that the inter-annual and seasonal abandonment rate of farmland in China from 2010 to 2018 were 9.79% and 5.11%, respectively. High values of inter-annual abandonment rates (>20%) mainly located in the agro-pastoral ecotone of northern China and the southern coastal area of China, as well as the TPR; while high values of seasonal abandonment rates (>20%) mainly concentrated in the YRR, the SER, and the HHH. The total FCPP of abandoned farmland amounted to 124.38×10^6 t/year. If 50% of the above FCPP can be achieved, an additional 154.72×10^6 people could be fed according to FAO's food security standard.

Submission ID: 308 Poster

MAPS: A New Model Using Data Fusion to Enhance the Accuracy of High-Resolution Mapping for Livestock Production Systems

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Abstract

To meet growing demand for animal-based foods, livestock production has intensified to maximize output with limited resources and space. This has increased the spatial heterogeneity of livestock distribution, which has in turn caused severe nutrient loss and increased risk of antimicrobial resistance, zoonotic disease, and human exposure to disease and pollution. There is an urgent need for spatially explicit impact assessments, but current methods lack the resolution needed to accurately map fine-scale livestock distribution. Here we developed a mapping agricultural production systems (MAPS) model by fusing enterprise registration information (ERI), which can directly represent agricultural activities, with other currently available data to generate high-resolution mapping. Using an example of pig production in China, the global leading pig producer, we show that MAPS improves the accuracy of location/size estimates of livestock production systems by 12%–84%, illustrating a 44% underestimation of pig numbers in dense farming areas (>1,000 pigs/ km2) by existing methods. MAPS also reveal a spatial transfer of pig production from rural to peri-urban areas, implying more decoupled pig-crop systems in China. MAPS enable spatially explicit impact assessments to support sustainable planning of intensive livestock production systems that can alleviate nutrient loss and health risks.

Track 6 Sustainable Cities and Regions

6a. Urban and Regional Transformations

Abstracts

Submission ID: 112

"HACKATHON+" As a Method to Integrate Civic Tech in Urban Planning: The Case of a "HackYourDistrict" Workshop in Taipei

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Abstract

In this study, we investigate the recent application of hackathons in urban planning, focusing on their role in data collection and public engagement. Despite their increasing use, hackathons have been criticized for being ephemeral events with limited long-term impact and a tendency to prioritize digital information over social context. The "Hackathon+" model, enriched by site visits, stakeholder reports, feedback, and data collaboration via Commutag, aimed to improve traditional hackathon approaches.

The research was conducted during the "HackYourDistrict" international workshop series, held in Taipei in October 2023. This event gathered over 20 international participants who collaborated with Taiwan's civic tech community. The focus was on the Guandu Plain, Taipei's largest remaining urban agricultural area, strategically located and ecologically significant. However, this area faces challenges from landowner and developer pressures for changes in urban planning zoning, and efforts by local young farmers to innovate in agriculture and cultural activities to redefine Guandu's identity.

"HackYourDistrict" was designed as a catalyst to introduce new perspectives and opportunities in Guandu's urban planning. Utilizing research methods including participatory observation, focus group discussions, and participant surveys, this paper explores the implementation of the "Hackathon+" case of aiming to expand the scope and potential of civic technology in urban planning and analytics. Through various simulation scenarios, this paper presents the Guandu "Hackathon+" case study, emphasizing the preserved values of urban agriculture and natural spaces. It underscores the potential of civic technology in knowledge production, transfer, and public communication within the realm of urban planning.

The "Hackathon+" study, focusing on the Guandu Plain in Taipei, aligns with the ISDRS conference theme "Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood" by emphasizing sustainable urban agricultural practices, civic engagement, and innovative solutions in urban planning. This approach supports SDGs such as Sustainable Cities and Communities (SDG 11) and Life on Land (SDG 15). The location of Guandu Plain, nestled between mountains and rivers, underscores the importance of preserving natural ecosystems (SDG 13: Climate Action and SDG 14: Life below Water) and the role of civic tech in enhancing knowledge production and transfer, contributing to Quality Education (SDG 4). Overall, the study presents a multifaceted approach to sustainable urban development, aligning with the conference's theme of fostering sustainable livelihoods through the interconnection of mountain and ocean futures.

Submission ID: 150

An Initial Exploration of Circular Urbanism in Taiwan's Construction Sector: Examining the Potential and Limitations of the BIM to CIM Approach

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Abstract

Research by the Ellen MacArthur Foundation indicates that half of the materials mined globally each year are used in the built environment. With urbanization, global material consumption is projected to increase from 40 billion tons in 2010 to 90 billion tons by 2050. This highlights the challenge of resource consumption if the current linear economic model persists. Concurrently, Schiller and Roscher (2023) merged the 'Closing, Slowing, and Narrowing (CSN) strategy' with the '9R framework' to advocate for circular urbanization. The CSN strategy includes 'Closing' for increased reuse of artificial resources, 'Slowing' through repair, remanufacturing, upgrading, and remodeling to extend lifespan, and 'Narrowing' for enhanced resource efficiency and reduced product and material consumption. Examining Taiwan's construction activities from a circular urbanization perspective is valuable. Taiwan is among the most urbanized countries globally, and a recent urbanization wave driven by science parks, spurring new residential and infrastructure construction demands. However, Taiwan's built environment material flow is complex, embedded in dynamic global material economy relations. On the other hand, about two-thirds of Taiwan's mining areas are in the east, reflecting regional resource production and consumption disparities. Under regulatory, environmental, and social conditions, construction activities in Taiwan face higher thresholds in natural resource extraction and waste disposal site operation. In response, Taiwanese government agencies are promoting the transformation of the construction sector through circular economy models. This research, as a pilot study of a larger project, explores using BIM (Building Information Modeling) and CIM (City Information Modeling) under 9R and CSN principles for simulations and decision-making to promote material circularity and reduce carbon emissions. The study focuses on Shezidao in Taipei, a sand dune area formed by the Keelung and Tamsui Rivers, with low population density and significant urban planning controversies due to recent land use zoning changes. The simulations provide new development perspectives for the government and community. The study first creates 3D models for Shezidao, comparing current scenarios with alternatives using different designs and recycled materials. It then uses GIS tools to calculate carbon emissions at neighborhood and regional levels, establishing preliminary CIM models. Further steps involve refining these models based on input from government units, community groups, and experts. The case of Shezidao, facing discussions of comprehensive reconstruction or partial preservation, offers scenarios for developing CSN strategies. The transition from BIM to CIM involves conceptualizing circular scenarios at different scales. The research discusses overcoming challenges through technological innovation and policy formulation, focusing on interdisciplinary collaboration and integration for effective circular urbanism strategies. It lays the groundwork for future studies on material flow analysis in different regions of Taiwan's construction activities. This study explores how Taiwan's construction sector can achieve sustainable development through circular urbanism, applying circular economic principles in design, construction, and use phases, particularly through BIM and CIM for material recycling and carbon emission reduction. It aligns with the conference themeby focusing on technological innovation and policy development to advance SDGs, especially SDG9 (Innovation and Infrastructure) and SDG12 (Responsible Consumption and Production).

Submission ID: 177

Urban Mobility in Hill Towns: Transformation towards Sustainable Development

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Abstract

Hill towns across the globe face unique urban mobility challenges. Their steep slopes, winding roads, and growing tourism overburden the existing infrastructure, leading to challenges such as congestion, air pollution, and limited accessibility. The traditional solutions often magnify these problems, hindering not only sustainable development but also equitable access for residents and visitors. This research aims to bridge the gap in understanding how hill towns can achieve mobility transformations that align with the Sustainable Development Goals (SDGs), particularly SDG 11. b (sustainable transport systems) and SDG 13.2 (integrating climate action into national strategies). Focusing on Shimla city, India, as a case study, the research investigates how the unique geographical and ecosystem complexities impact mobility transformations. Through diverse data collection methods, including local surveys, and stakeholder interviews, the study sheds light on the distinct needs and challenges faced by various user groups — residents, tourists, and individuals of varying socio-economic backgrounds and abilities. Opinions involved reflect the concerns of residents regarding congestion and pollution, the tourism industries' emphasis on responsible development, and the environmental group's call for reduced carbon emissions and active travel promotion. The research examines successful approaches used in other towns worldwide, focusing on solutions that promote gender equality, inclusiveness, and environmental sustainability. This analysis informs the development of context-specific strategies for Shimla, considering local needs, infrastructure limitations, and budget constraints. These strategies address challenges like integrating active travel options with the challenging terrain, implementing affordable and accessible public transport, and ensuring collaboration between diverse stakeholders for co-creating and managing sustainable mobility systems. Ultimately, this research aims to provide valuable insights for Shimla and other hill towns seeking to navigate the intricate path towards equitable and sustainable mobility transformations. By prioritizing inclusivity, environmental responsibility, and effective management, hill towns can strengthen their transportation systems by ensuring the well-being of their inhabitants and protecting the fragile ecosystems that are vital to their identities and locals. This study contributes to a broader discourse on achieving the SDGs in challenging geographical contexts, paving the way for future research and action towards a more inclusive and sustainable future for all.

Submission ID: 178

Policy Analysis of Urban and Regional Transformation in Indian Temple Towns: A Framework for Sustainable Development

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Abstract

Policies serve as the blueprint for urban and regional development, shaping infrastructure, economy and societal aspects. And aligning policies with SDGs, particularly SDG 11 on Sustainable Cities and Communities, is vital for a strategic and inclusive approach as it ensures lasting impact on the economic, cultural and environmental dimensions. Recognizing the significance of temple towns in India, policy alignment not only preserves the cultural heritage but sustains community identities. The study evaluates government policies related to urban and regional transformation in Indian temple towns, understands how existing policies align with or diverge from the SDGs, and creates a deeper understanding of the dynamics between policies, sustainability and cultural heritage. The research employs qualitative and exploratory methods and will be based on primary and secondary data sources consisting of policy analysis, comparative case study analysis, interviews with policymakers and heritage conservation organizations, on-site visits, and focus group discussions with local communities. Specific temple towns in India will be examined as case studies to understand the practical impact of these policies. The current policies governing the changes in Indian temple towns will be studied and assessed to see the effectiveness of these policies in achieving sustainability goals. Subsequently, a framework will be developed to synthesize findings from policy analysis, and comparative analysis, and propose targeted interventions that can enhance current policies for better alignment with Sustainable Development Goals. Furthermore, a policy gap analysis matrix will be done to offer a clear overview of where policy improvements are needed, supporting policymakers in strategic decision-making. Overall, the framework will systematically address the policy gaps, identify patterns of transformations in the policies, and aim to provide recommendations for policymakers to align with SDGs. The study not only analyzes policies shaping the Indian temple towns, but provides a systematic framework for policymakers, urban planners, government agencies, heritage organizations, communities, and researchers. As temple towns continue to evolve in India, this paper advocates for policies that incorporate Sustainable Development Goals ensuring economic prosperity, cultural preservation and environmental stability.

Submission ID: 217

Optimizing Investments for the Path to Holistic Sustainable Development through Achieving Human Satisfaction: A Particular Reference to the Urban Transport Sector in Sri Lanka

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Abstract

In pursuit of sustainable livelihood, the focus on the 2030 Agenda for Sustainable Development has emerged as a significant and compelling topic among stakeholders engaged in global development projects. Concurrently, in today's global landscape, numerous researchers are trying to redefine sustainable development by integrating subjective goals, such as human happiness and satisfaction together with already established objective goals like environmental, economic, and social wellbeing. Sri Lanka, a nation historically entrenched in traditional development approach, has grappled with economic crises stemming from weak investments and unsustainable debt, leading to a surge in migration due to dwindling life satisfaction among its populace. Moreover, Sri Lanka faces a number of environmental challenges, necessitating the adoption of a unique holistic approach to sustainable development that integrates both subjective and objective goals. This approach seeks to optimize returns from developmental initiatives while safeguarding the mental and spiritual wellbeing of its citizens.

This study is particularly focused on the urban transport sector, which not only significantly impacts the economy but also serves as a major contributor to greenhouse gas emissions and other pollutants. Furthermore, urban transport profoundly affects citizens' daily lives, influencing their time, costs, and overall activities. The research utilizes literature surveys and quantitative analyses from primary and secondary sources. The paper's findings highlight the conditions which impact on the human's mental wellbeing with reference to accepted philosophies related to mental wellbeing and relationship of both subjective & objective goals with the urban transport sector.

The study's findings highlight the inadequacies of current transport and city development strategies in comprehensively addressing both subjective and objective sustainable development goals within the transport sector. Notably, the research underscores the potential efficacy of prioritizing investments in public transport infrastructure, rectifying existing failures, and fostering human-centered approaches to urban development. These strategies are identified as an avenue for achieving a harmonious balance between subjective well-being and overarching environmental, social, economical & cultural sustainability objectives. Moreover, the paper emphasizes the need for further research to delineate specific governance-led actions required to enact these transformative measures effectively.

Full Papers

Submission ID: 70

Expansion Opportunities of Railway Network of the Lisbon Metropolitan Area: A GIS-Based Methodological Study

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Abstract

The research focuses on enhancing the public transport system of the Lisbon Metropolitan Area's (AML), to reduce greenhouse gas emissions and reliance on cars, which currently account for 68% of motor transport. The study identifies gaps in the existing network and proposes improvements, focusing on light rail solutions. Using a GIS-based methodology, areas with the greatest mobility shortcomings were pinpointed by integrating data on population density, concetrated demand points, existing network and previous proposals for new developments. The study identified eight major gaps and proposed 18 light rail solutions, including new lines and network extensions. Performance indicators such as service provided, network density, and CO_2 savings were used to assess these proposals. The results suggest significant improvements: at the scale of AML, the proposed improvements would increase the population within 500 m of rail from 33% to 65%, boosting rail density from 0.11 km/km² to 0.17 km/km², and raising the public transport modal share from 16% to 43% of total no. of movements. These changes could cut CO_2 emissions by approximately 11%. The study demonstrates that an integrated, intermodal network could further enhance these outcomes and serves as a useful decision-making tool for similar contexts.

Introduction

Climate change is a major global challenge, caused by the high concentration of greenhouse gases (DG CLIMA-EU, 2023). The transportation sector is one of the major emitters, especially due to the use of combustion vehicles, with a total output of 8.7 $GtCO_2$ Eq. in 2019 (IPCC, 2022). Decarbonization and electrification are therefore necessary measures to achieve climate goals, with a focus on promoting rail transportation, which emits less 35% of CO_2 eq./pkm compared to the road alternatives (IEA, 2019).

In addition to emissions, the use of cars also affects quality of life and urban planning, while public transport modes promote densely populated areas while road-based transportation has a dispersing effect (Creutzig *et al.,* 2020). The Lisbon metropolitan area (AML) isn't an exception. After years of disinvestment in public transport, its inhabitants are now faced with a mobility system that is at the limit of their capacities and shows obvious signs of degradation. These characteristics reflect in the distribution off modal share, with 57% of users using individual transport compared to 13.3% who use the public alternative (INE, 2021).

In view of this reality, it is relevant to study a transportation model based on collective modes, which aims at a definitive change in the mobility paradigm in AML. The objective of this work is therefore to identify the gaps in the public transport network in the AML and explore proposals for improvement of the metropolitan light rail network.

Literature Review

Removing physical barriers to facilitate access to all spaces and ensuring access to means of transport for people with disabilities is a priority (May, Kelly and Shepherd, 2006). However, accessibility is not limited

to people with limitations in mobility, but also to all other users, so it is important, for example, to facilitate access to information (May, Kelly and Shepherd, 2006; Næss *et al.,* 2019).

The proximity of transport systems to populations is important to attract users, reduce dependence on individual transport and promote an organized urban structure. Studies show that demand decreases by 2.9% to 10% for every 10% increase in pedestrian distance to public transport access points (Zhao *et al.,* 2003; Ewing and Cervero, 2010).

In the literature, the reference values for the distances that users are willing to travel to use public transport range from 400 to 800 m. These values depend on factors such as climate, age, economic conditions, safety, frequency, and reliability of the service (Lee and Moudon, 2006; Daniels and Mulley, 2013). The mode of transport also plays a role, with rail modes allowing travel over longer distances, while road modes are more local (Daniels and Mulley, 2013; Van Soest, Tight and Rogers, 2020). In Spain, which has similar characteristics to Portugal, the reference distances for the Madrid metro system are 420 m, and studies for LRT systems assume a radius of influence of 500 m (Pantiga-Facal and Plasencia-Lozano, 2022).

In passenger transport, a network can include different modes of transport, such as public transport and private vehicles (Redman *et al.,* 2013). This intramodality, when carefully planned, translates into a variety of benefits to the user, making it possible to save money and time, thus promoting sustainable development to the urban environment (Kumar, Parida and Swami, 2013).

A transport system must be at the service of the population, providing greater comfort and frequency of service specialty where the demand is higher. This demand can be induced through points of interest, such as stadiums, urban centers, or hospitals, which generate movement must be served by high capacity means of transport (Cirianni, 2004; Ingvardson and Nielsen, 2018).

The implementation of transportation networks should still be subject to a feasibility assessment. For certain routes and parameters, different modes of transport with different capacities, costs, and technical requirements must be evaluated (Kołoś and Taczanowski, 2016; Basnak, Giesen and Muñoz, 2020). For an LRT system, its viability is assumed from a minimum population threshold of 200 000 inhabitants, and with a minimum population density in the catchment area of 1500 to 2200 inhabitants/km^2 (Gordon, 2011; Flannery *et al.,* 2015; Pantiga-Facal and Plasencia-Lozano, 2022). Thus, for cases in which these conditions are not met, other more economical solutions can be used, such as Bus Rapid Transit (BRT) (Kołoś and Taczanowski, 2016; Basnak, Giesen and Muñoz, 2020; PantigaFacal and Plasencia-Lozano, 2022).

One of the key factors in transport systems is the offer of the service, one of the factors that has the greatest influence on users in frequency (Redman *et al.,* 2013). From an operational point of view, it is important to save resources, in contrast to the interests of the public who want a greater offer. To find a middle ground, a minimum offer must be stipulated regardless of demand, to provide a base level off quality in the service (Soehodo and Koshi, 1999); the higher the frequency the better the service tends to be, and consequently the greater the demand for it (Rodrigue, 2020). Jha, *et al.* (2007) developed a GIS model for railroad layout in Washington D.C. In a study on LRT systems in Spain, Pantiga-Facal and

Plasencia-Lozano (2022) used GIS to inventory and test parameters. The stations have a minimum population density of 1500 inhabitants/km2 and vary in the number of potential users. The maximum distance between stations is 685 meters. The smallest population considered is 200 000 inhabitants in Santa Cruz de Tenerife. The lines range from 2.2 km to 112 km, and the minimum utilization rate is 26% by the potential population.

Methodology

The study of opportunities for improving and expanding the light rail network in the Lisbon Metropolitan Area follows a methodology that has already been applied in other studies and has been covered in scientific literature. This is shown in Figure 1.

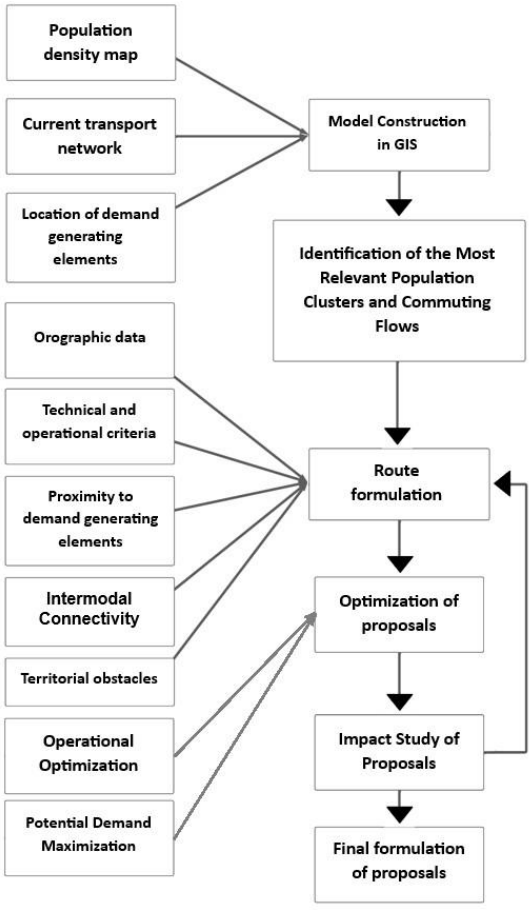

Figure 1. Methodological diagram.

The study considered the existing transport network and the one currently being implemented. The aim is to intervene not only in the capital's intra-urban mobility, but also in travel within and between the main urban centers of the metropolis, outside the city of Lisbon. A road-based solution does not seem to be an adequate answer to solving Lisbon's transportation problems. This study is therefore focused on light rail modes.

The points generating demand were cross-referenced with information on the main commuter flows in the AML and the population density map. The latter was obtained from the National Statistics Institute (INE) in the 2021 census data. This methodology follows that of the studies carried out by Jha, *et al.* (2007) and Pantiga-Facal and Plasencia-Lozano (2022). The following elements were identified as providing demand for transport systems: Events venues, Sports venues, Universities and secondary schools, Commercial areas and services, Hospital centers, Interfaces, Population density. The demand-generating points mentioned above were identified manually and inserted into the GIS project as shown in Figure 2.

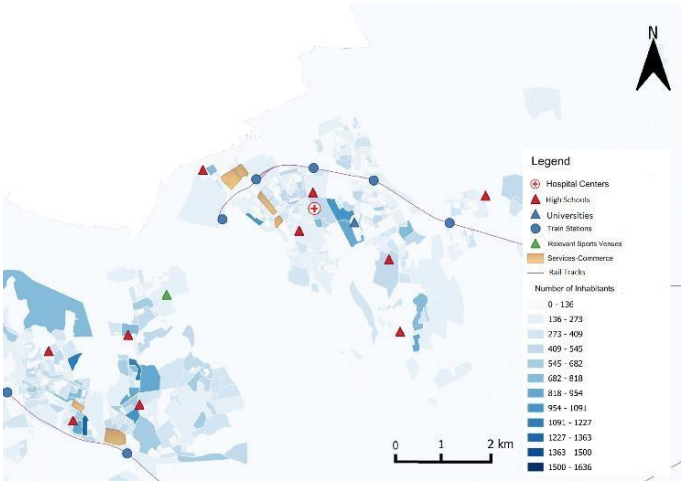

Figure 2. Population distribution of Barreiro and Seixal with their respective movement generating points

The analysis also considered technical requirements such as topography (maximum slopes of 6%), physical obstacles, operating speed (maximum 60 km/h), interval between circulations and rolling stock, gauge (European standard 1 435 mm gauge), average running speed, (21.6 km/h for surface light rail, 31.9 km/h for underground), as practiced by the Metro de Lisboa (ML) and MTS networks.

Figure 3 shows two proposed layouts for LRT, developed through the urban fabric along existing wide roads or vacant land, to avoid conflicts with road traffic and expropriation. These routes and their respective stops have been proposed in locations that reach the generating points and the most populated areas, as shown in Figure 2. This range for the LRT, represented in Figure 3 by the red circles (Buffer), has a value of 500 meters and reflects the distance users are willing to travel to use the proposed means of transport.

This value for the Buffer is in line with the values suggested in the literature, which indicate 500 to 800 meters for surface or depth meters (Daniels & Mulley, 2013; García-Palomares *et al.*, 2013; Van Soest *et al.*, 2020). However, as Portugal has an aging population and a hot climate, it was decided to adopt the value of 500 m (García-Palomares, Gutiérrez and Cardozo, 2013, p. 1097).

In the case of the train, the value assumed in the literature suggests a radius of between 800 and 1 200 m, as it is a means of transport that offers more distant destinations and runs at higher speeds than the metro. Therefore, for the same demographic and climatic reasons mentioned above, the value of 800 m is assumed as the Buffer.

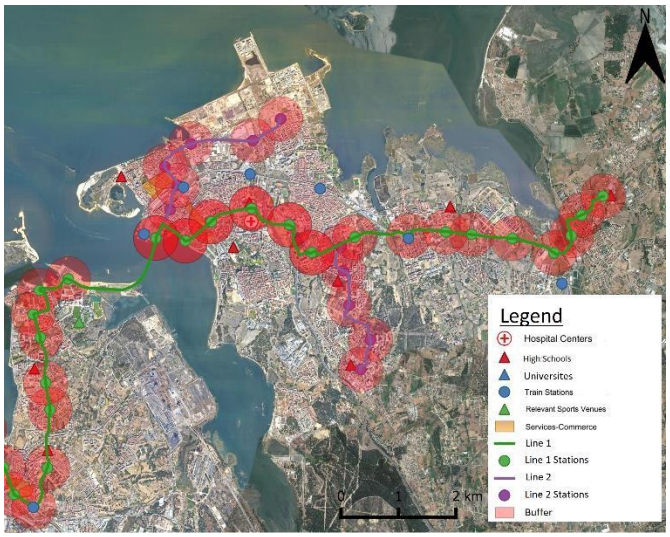

Figure 3. The cities of Barreiro and Seixal with their respective movement generating points, a schematic of two proposals and their respective influence buffers

There are special cases in the AML of axes with high passenger traffic that cannot be identified by the criteria defined in the aforementioned methodology, but whose integration is relevant to the objectives of this study. We used public data from the 2021 Census, building an origin-destination matrix for AML for trips made daily by private cars and mobility studies by TML (2017) and ML (2023b).

To assess the impact of the final proposal on the dynamics of mobility in the AML, performance indicators defined in the literature were used: modal distribution of daily transport use, population served by rail, density of rail network, number of vehicles withdrawn from circulation, and direct greenhouse gas emissions.

To determine the number of vehicles withdrawn from circulation (VRC), the eligible vehicles were determined using the origin-destination matrix of individual road vehicles from the 2021 Census. Scenarios were defined according to % of population living within a 500 m radius of a train station who are willing to leave their private vehicle to use the public transport. Two scenarios were defined: 42% (Pantiga-Facal and Plasencia-Lozano, 2022) and 59% (Dirkx, 2012).

To calculate the CO_2 eq. saved, the VRC was multiplied by the emission factor for each vehicle (CO_2, N_2O and CH_4), and this by the average daily km traveled per vehicle in the AML. These correspond to 153.5g CO_2/km (EEA, 2023), 0.000 013g CH_4/km, 0.000 01g N_2O/km (ML, 2023a) for vehicles with an average age of 15.2 years (ACP, 2021) and 13.3 km (INE, 2021) respectively.

To calculate the effect that the proposals have on the modal distribution of the AML, the VRC of each proposal was converted into a percentage of the total number of vehicles in daily circulation, 1.48 million (INE, 2021).

The indicator of the population served by rail was calculated using GIS tools by intercepting the population within a radius of 500 m from a metro station and 800 m from a train station, as suggested in Figure 3.

Although an economic analysis is outside the scope of this study, we checked that the proposal complies with published feasibility criteria. The literature considers an LRT system to be viable when it has a minimum density in its catchment area of between 1500 and 2200 inhabitants/km^2 and a total population of more than 200,000 inhabitants (Gordon, 2011; Flannery *et al.,* 2015; Pantiga-Facal and Plasencia-Lozano, 2022). However, in specific cases of operation such as tram-train or LRT feeder systems, minimum population density ranges as low as 1200 inhabitants/km^2 can be considered (Pantiga-Facal and Plasencia-Lozano, 2022).

Results and Discussion

The AML Public Transit System

Within AML, with a total population of 2.8 million, the municipality with the largest population is Lisbon, with more than 500 000 inhabitants, in addition to the large concentration of companies and services. Despite the large population, in contrast to other international examples, the AML has a low population density (only 932 inhabitants/km^2). Compared to the metropolitan area of Vienna, the Austrian capital, which has the same population as the AML but with a density four times higher, of 4 326 inhabitants/km^2), as shown in Figure 4. This is reflected in the efficiency of the operation of public transport.

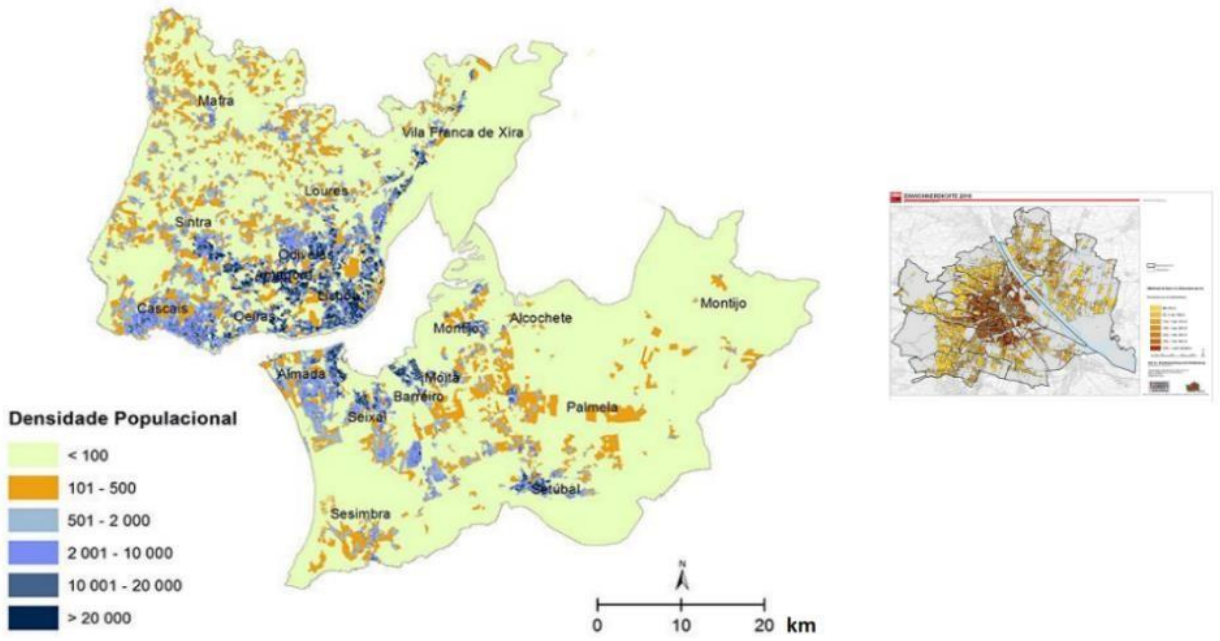

Figure 4. Comparison between the population density of AML and Vienna.
Source: Ministério das Infraestruturas, 2022

The diverse options of public transport cannot respond with quality to the mobility needs of the population, which is reflected in a high use of private vehicles, as shown in Figure 5.

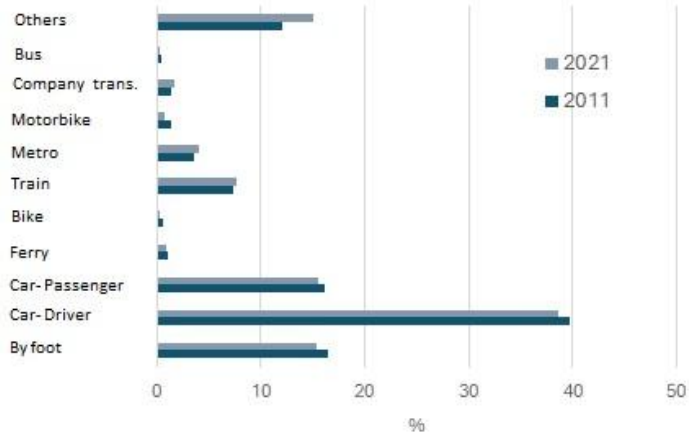

Figure 5. Modal share in the Lisbon metropolitan area by number of trips.
Source: Censos 2021. Note: the "others" include multi-modal trips. In the Census there is no info on distance travelled

The transport network in Lisbon has several modes of transport that serve the AML territory. There are suburban train lines that connect surrounding towns to Lisbon. Frequencies range from 10 to 30 min (CP, 2023; IP, 2023b). Currently, the system is saturated at several points and operators do not have new rolling stock to reinforce the offer (Expresso, 2023).

Travel within Lisbon is mainly done by metro (underground), tram, and bus. The metro has been operating since 1948, with 56 stations and 4 different lines, as shown in figure 6, with electric trainsets with a maximum speed of 60 km/h (ML, 2023a). It is the main option for fast commutes within the city, although off-peak intervals can be as long as 20 min.

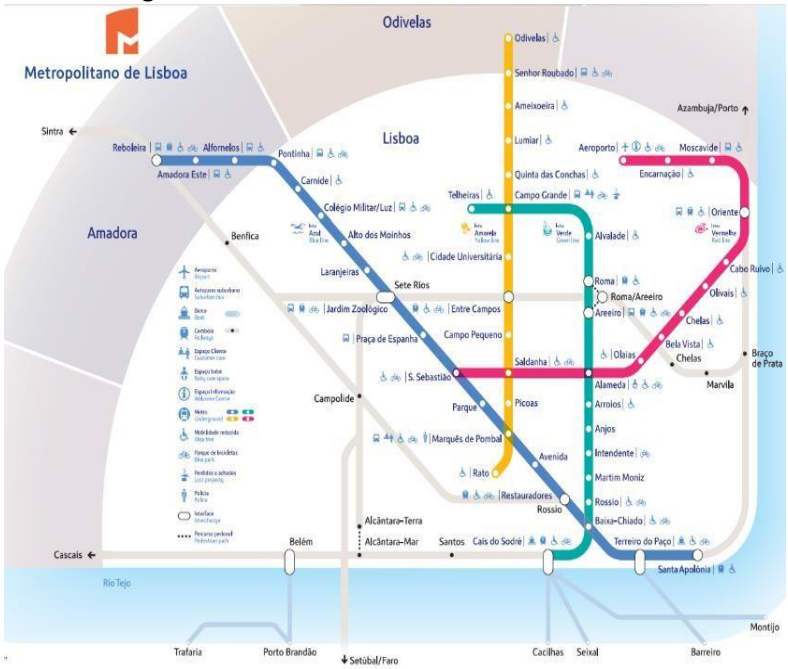

Figure 6. Diagram of the Lisbon metro network. Source: Lisbon Metro, 2023

Trams and buses in Lisbon are operated by Carris. The bus network in AML is operated by Carris Metropolitana, created in 2022 to unify several operators under a single brand, standardizing fleets, schedules, fares, and service quality (Carris Metropolitana, 2023). Despite the improvements, the low frequency on some lines still makes it difficult to use.

In Almada, on the left bank of the Tagus River, there is an LRT system called Metro Sul do Tejo (MTS, 2023). The network of 3 lines, represented in figure 7, serves various points of interest, such as universities, train stations, schools, and ferry piers (IP, 2023a; MTS, 2023).

River connections between the two banks of the Tagus River are made by ferries, which connect several cities on the left bank (Almada, Montijo, Barreiro, Seixal, Trafaria) to Lisbon through the interfaces of Cais do Sodré, Belém and Terreiro do Paço (TTSL, 2023b). From these points, passengers can use other modes of transport, such as train, metro, or bus, to reach their destination (TTSL, 2023a).

Figure 7. Diagram of the Southern Transport Metro (MTS) network

Source: MTS, 2023

The *Navegante* pass exists since 2019. This initiative allows, for the price of €40, to make use of all means of public transport throughout the AML for one month without limitations (AML, 2023; Navegante, 2023). For occasional journeys there are single-use or rechargeable tickets. In addition, there are also social initiatives that aim to support young people, needy families, and the elderly with discounts on the purchase of transport tickets (AML, 2023).

Performance of Expanding Opportunities for Light Rail

Based on the methodology presented, 8 spots were identified, marked in green in Figure 8.

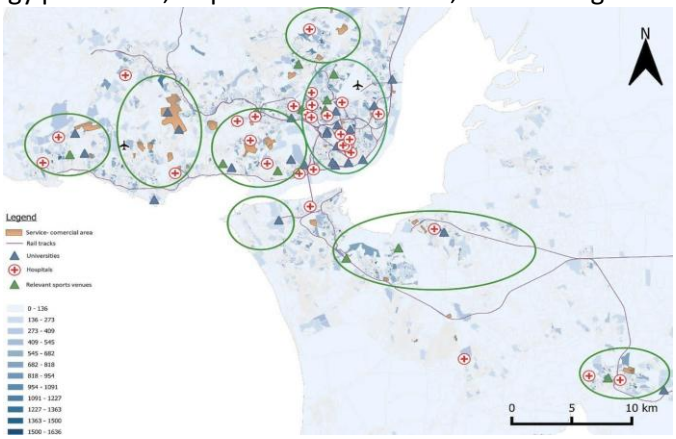

Figure 8. GIS-generated map showing the distribution of the areas with the greatest lack of mobility in the AML

The matrix shown in Figure 9 shows the axes with the highest annual traffic between the various Lisbon Metro stations by direction. The symbiosis between the train and the metro can be seen when you compare different stations

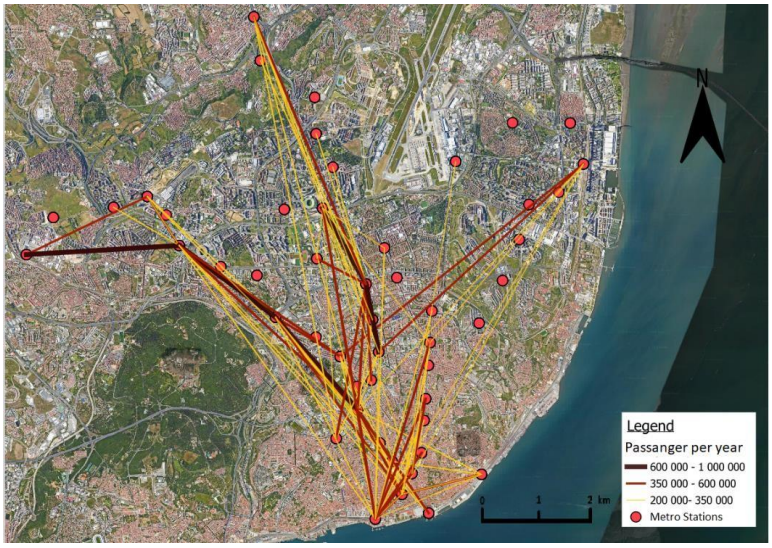

Figure 9. Origin and destination matrix of Lisbon Metro users: weighted average 2019 and 2022

The busiest stations are those that allow passengers to transfer between different lines of the network, or to Lisbon's suburban trains. Cais do Sodré stands out as having the highest annual passenger traffic, and this interface includes the Cascais Line suburban trains, as well as river and road connections. Figure 10 summarizes the proposals for the new mobility systems for AML.

The new proposals include 3 new LRT systems (Oeiras, Cascais and Loures), 4 extensions of existing LRT systems (Trafaria, Costa da Caparica, Moita and Barreiro), and 4 extensions of the existing Lisbon underground metro network (Algés, Infantado, Hospital Amadora-Sintra, and Campo Grande).

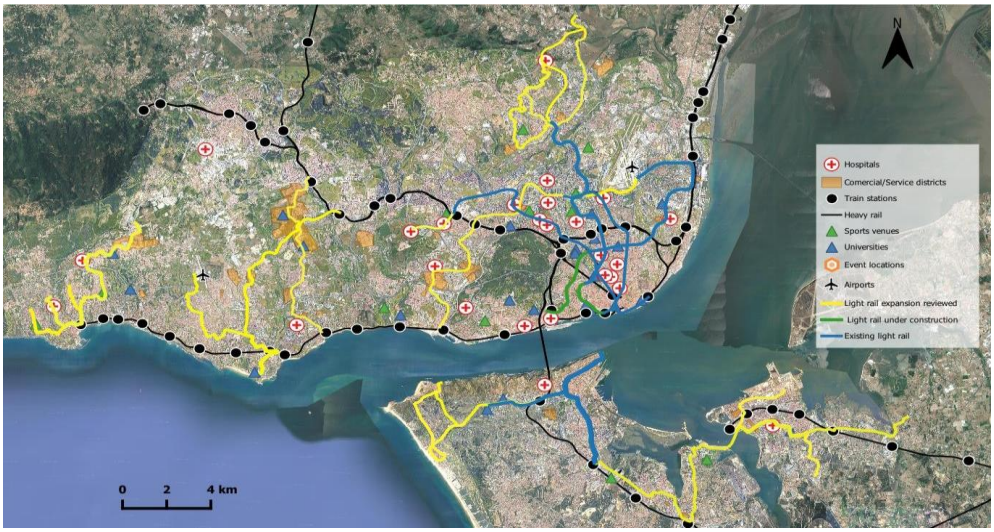

Figure 10. Proposals for new Metro systems in the AML.

The overall performance of the AML rail system was compared in three scenarios for the indicators of the population served by rail transport, and in the evolution of modal distribution:
Scenario 0 evaluates the indicators according to the current network.

Scenario 1 assumes the completion of all the projects currently under construction, being studied or with a high probability of being completed in the short/medium term (violet line, circular line, extension of the red line to Alcântara, and LIOS).

In scenario 2, all the proposals presented in this paper are added to the projects in the previous scenarios. Sub-scenario 2a corresponds to a conservative "P" parameter of 43%. Subcenario 2b corresponds to an optimistic "P" parameter of 59%. The "P" parameter represents the percentage of the population within a 500 m radius of a station that uses PT.

The percentage of the AML population served by rail is shown in Figure 11. 32% of the population is within 500 m of a stop or station, a far cry from the current situation in Madrid, where the figure is 73% (García-Palomares, Gutiérrez and Cardozo, 2013; Marks, 2016; Statista, 2023) or Vienna, which serves 71% of its population (Wiener Linien, 2021).

The density of the rail network (Figure 11) currently stands at 0.11 km/km^2. In scenario 1, the percentage of the population served rises to 36%, a difference of 4%. In scenario 2, the percentage of the population served rises to 65%. However, this figure is still lower than Madrid or Vienna.

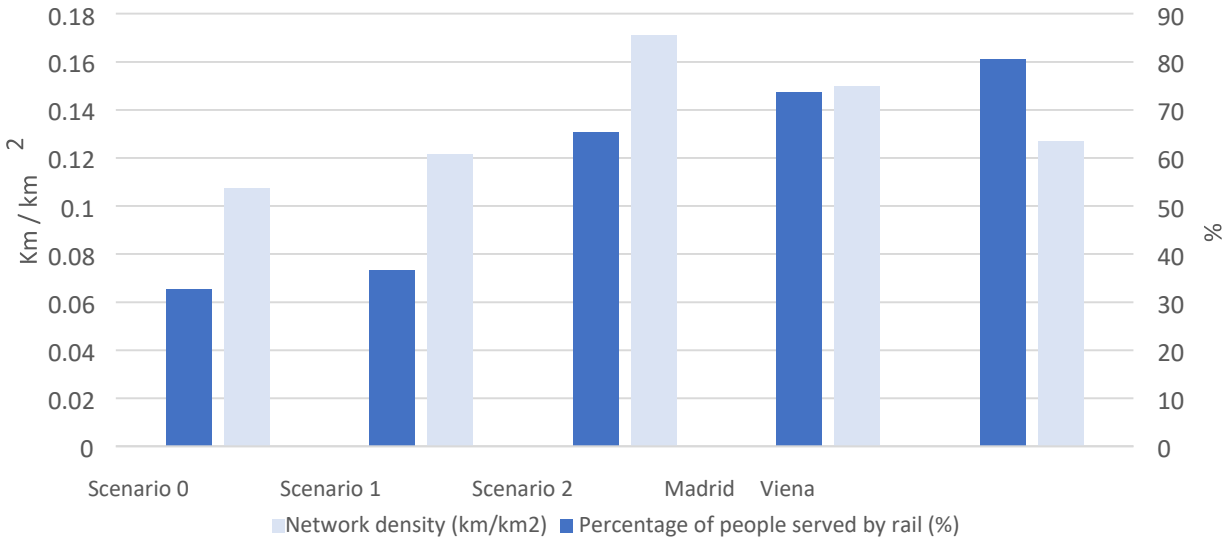

Figure 11. Percentage of population served by rail in a radius of 500 m at the left, and network density at the right for the AML, Viena, and Madrid. Adapted from Wiener Linien (2021)

The evolution of the modal shift according to Scenarios 0, 1, 2a and 2b, shown in Figure 12. Of all the journeys currently made, only 13% use public transport, while 57% use individual transport. In scenario 1, these percentages change to 54% for IT and 16% for TP. In scenario 2a, the percentage of journeys using PT rises to 29%, while in the most optimistic scenario2b, PT reaches a modal share of 36% (of no. of trips).

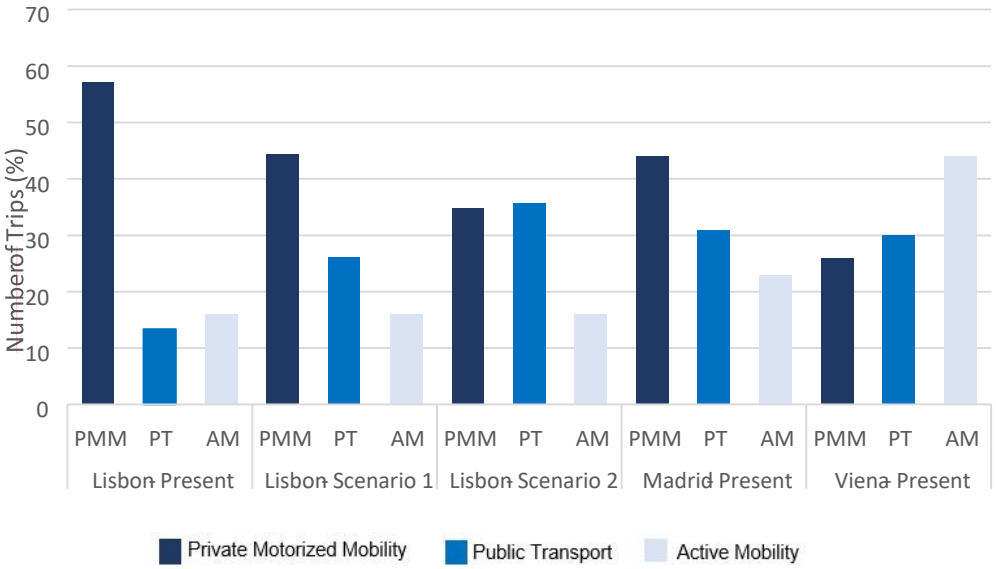

Figure 12. Number of travels per mode of transport according to each scenario, comparing toMadrid and Viena
Adapted from EEA (2011), Wiener Linien (2021) and Censos (2021)

The significant improvement in access to transit is reflected in CO_2 emissions and the number of vehicles on the road. Looking at the graphs in Figure 13 and Figure 14 respectively, there is a decrease of approximately 231 kt CO_2 eq. per year, and 218 000 vehicles per day in the most optimistic scenario.

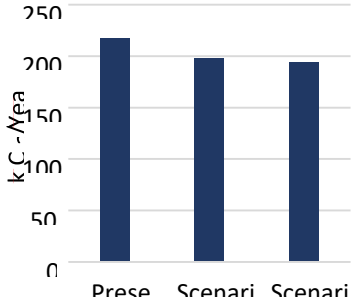

Figure 13. Total emissions of CO_2 eq. (thousand tons annually) for each scenario, for the transport sector in the AML

Considering the annual CO_2 eq. values for the passenger transport sector in AML indicated by the national emissions inventory (3613 kt/year), there is a percentage reduction of between 8% and 11% in emissions.

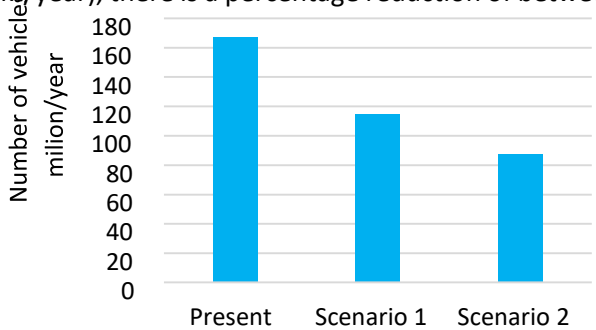

Figure 14. Number of vehicles taken out of circulation daily for each scenario

Conclusion

The text addresses the critical role of changing mobility habits to combat climate change and air pollution, particularly in large cities. Emphasizing collective transport, low CO_2 mobility as the most effective strategy, the text highlights the embryonic stage of this effort in the Lisbon Metropolitan Area (AML) due to years of underinvestment in public transport. Although political discourse and some projects are underway, real improvements in network performance indicators like modal shift, journey times, service frequency, and fare integration have yet to be seen.

The study identifies areas in AML lacking effective mobility solutions, proposing 18 railway solutions for eight zones: 13 light rail systems and 5 heavy rail solutions. Based on international studies, particularly from Madrid, the study found that implementing these proposals would increase the population served by public transport from 32% to 65% and the railway network density from 0.11 km/km² to 0.17 km/km². This would align AML's network density and public transport usage with cities like Madrid, potentially leading to higher demand for public transport.

The literature and results suggest that expanding the railway network, coupled with improved intermodal services, would enhance modal shifts, and reduce greenhouse gas emissions. Optimistically, the collective transport share could increase from 13% to 36% of total trips, reducing individual vehicle use by 11% to 15% and cutting passenger transport-related greenhouse gas emissions by 8% to 11%. However, AML's lower population density compared to Madrid and Vienna poses a challenge to mobility system efficiency, necessitating complementary measures for car circulation, soft modes, and urban planning.

The study concludes that sustainable transport modes must become a reality soon, involving significant changes in habits and paradigms to avoid irreversible effects on humanity. Future research should focus on a genuinely integrated metropolitan transport network, examining the practical viability of proposed expansions. The methodology did not include non-rail axes with significant demand, suggesting further study of alternative mobility solutions. Additionally, integrating cycling networks into public transport and implementing measures to encourage public transport use, such as simplified integrated ticketing, ubiquitous user information systems, and accessible park-and-ride facilities, are recommended.

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Decentralized WASH in Informal Settlements: A Step towards Sustainable Development

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Abstract

Nepal is prone to multi-disasters from natural and anthropogenic causes. Flooding and resulting inundation in the Terai areas of Nepal is increasing, partly due to climate change. The low elevation of the informal settlements along the Singhiya River in Biratnagar Metropolitan City in the Terai area of Nepal, elevated highways in the downstream areas, and lack of proper drainage and sewerage systems are exacerbating the Water, Sanitation and Hygiene (WASH) problem in Singhiya riverbank. The extremely low per-capita income of the Singhiya settlers, low priority to WASH in informal settlements and lack of WASH awareness are some of the root causes of the pathetic hygiene and sanitation condition.

The global paradigm shift in the water sector and the demand to focus on local community level for efficient and sustainable water services, promoted decentralized WASH systems. Using freely available maps and GIS software, the spatial extent of the problem was mapped. A field visit to the area was conducted to document the extent of the problem and the willingness of the local settlers to contribute to decentralized WASH at Singhiya. To address the problem in a sustainable manner a technical design of the solution, in the form of a piloting project is proposed.

***Keywords**: WASH, sustainable development, informal settlement, flood, inundation*

Introduction

Nepal is prone to multi-disasters due to a combination of natural and human factors. It is vulnerable to natural disasters due to its topographic features, but human activities may intensify the risks further. Flooding is one of the most common natural disasters affecting Nepal. The principal and most destructive type of flooding is from rivers (fluvial) located within the Terai region. During the prolonged and intense precipitation events in the monsoon season, the river channels cannot hold the flood water and overflows in the adjacent areas, called flood plains, causing inundation in the river side settlements for several days each year. The disaster resulting from this phenomenon is getting more prominent in the recent years in the Terai areas of Nepal due to soil erosion, high sediment yield, riverbed aggradation, riverbank encroachment, unplanned river training works, elevated highways south of the Nepal-India border, and climate change (Adhikari, 2013). Not only access to clean and safe water becomes a critical issue when the area is flooded but water-borne diseases also significantly spread across the settlements.

The problem is further exacerbated by the political and administrative vicissitudes in Nepal in the last few decades which resulted in generation of a class of people without formal identification and citizenship and therefore without access to resources and a right to own land, referred as informal settlers, usually are informally residing alongside the riverbank. These people are very poor and are forced to settle in flood hazard prone public land without a land ownership certificate along flood prone rivers. This study

focuses on water sanitation issues for the informal settlements along the Singhiya River in Biratnagar Metropolitan City (BMC) in the Terai area of Nepal. The low elevation of the place, and lack of proper drainage and sewerage system are exacerbating the water sanitation and hygiene (WASH) problem. The extremely low income of the Singhiya riverbank settlers, apathy from the local governance system, and low WASH awareness are some of the root causes of the low hygiene and sanitation level in this area.

The main objective of this study is to develop a decentralized cost-effective simple WASH system that can be operated and maintained by the intended beneficiaries of the project on household level. After a literature review and a field visit by some authors, it proposes a technical design of a toilet and septic tank system which can withstand inundation, prevent cross contamination domestic water sources from overflowing of cesspool.

This paper is organised as follows. Flood prone zone in Nepal is briefly covered by focusing on the study area (Singhiya) where informal settlers are facing water issues in an ongoing basis. The concept of decentralised WASH is reviewed briefly to see how it could be a viable solution in the area. Certain steps are followed to see how the solution may be implemented in the affected area. A technical design is provided for a practical outcome. A conclusion is drawn at the end.

Background

Flood Prone Zone in Nepal - Terai Regions

The Terai regions of Nepal are particularly susceptible to river flooding during the monsoon season as they are natural floodplains. During the monsoon months from June to September in Nepal, most of the rivers in Terai experience high water flow exceeding its normal capacity by causing them to overflow (flooding) and inundation of surrounding areas (Adhikari, 2013). On average, floods cause over 175 deaths each year and average annual economic losses exceeding USD 140 Million and Nepal is the tenth highest country in the world in terms of relative physical exposure to fluvial flooding (Asian Development Bank, 2022).

The selected Singhiya settlement for this study is located within Biratnagar Metropolitan City, South East part of the country. Figure 1 shows within the map of Nepal.

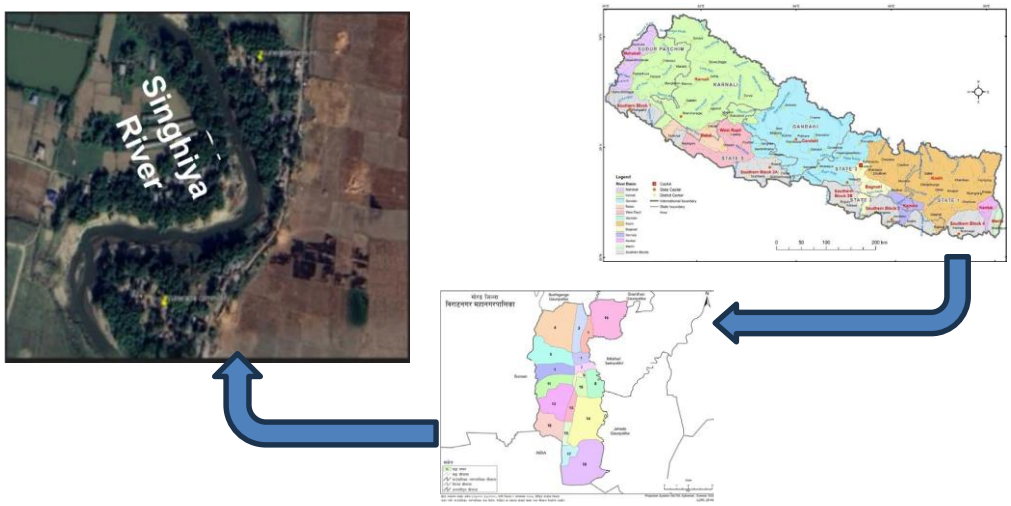

Figure 1. Location of Singhiya settlement in Biratnagar Metropolitan City

There are ten informal settlements along the Singhiya riverbank in Ward No. 19 of BMC. Each settlement has approximately 40 to 50 small huts with an average of 4 people living in each hut. The sanitation facilities in this area consists of household tubewells located close to the unsealed cesspools. Singhiya settlement is annually flooded and inundated for several days during monsoon flooding season. The flooding and inundation result in overflow of the cesspool which contaminates the surface area and shallow aquifer, which are the water source of the tubewells, with fecal materials, resulting in very low hygiene and the settlers getting gastrointestinal diseases.

Figure 2. Map of informal settlements along the Singhiya riverbank (Supplied by Eco Concern)

Everyone in the area is forced to consume flood water. Sanitation is difficult since (i) the toilet is flooded, (ii) the septic tank is under water which easily contaminates tap water, (iii) the unconfined shallow groundwater is contaminated. All these conditions result in very poor hygienic environment and the health condition of residents deteriorates.

Figure 3. A condition of drinking water for Singhiya settlers (Source: YouTube)

Decentralised WASH as a Solution

Traditionally, the concept of water-sanitation-hygiene (WASH) includes, in terms of water supply, large scale infrastructure construction involving (a) weir or dam to store or divert water in case of a surface water based project or well fields to withdraw groundwater from shallow or deep aquifer, (b) water treatment system with primary to tertiary water treatment facility, (c) main and branch pipes to transport water to distribution centers, and (d) laying of smaller diameter (typically 12.7 mm diameter) water distribution pipes to the intended individual households. For sanitation, the grey and black water from the household and other uses are collected through an elaborated network of pipes and manholes, treated and released to rivers or other water bodies. Proper use of water and sanitation results in better hygienic conditions. This system is typically centralized, with large annual budget allocation and a team of technical and management experts to manage the system (Hutton & Chase, 2017). All sort of waste water including grey and black water are managed properly. However, for any remote and sparsely populated areas of developing countries, it is challenging to set that up. For informal settlers, the problem is even magnified due to many complications including citizenship issues.

Decentralized sewerage system is defined as the collection, treatment, disposal / reuse of sewage from individual homes, clusters of homes, isolated communities or institutional facilities, as well as from portions of existing communities at or near the point of waste generation. Decentralized Waste Water Management System (DEWATS) involves sewage treatment and resource utilization for isolated habitations. This system to provide sustainable solution to sanitation problems in informal settlements have been discussed in different countries. One of the promising technologies was found to be the safe water garden (SWG) used in Indonesia. The Safe Water Gardens project developed a design of decentralized sanitation system for rural settings in Indonesia. It is a simple single-sized sewage treatment system developed from an original UNICEF concept, as shown in Figure 4 below. It suits individual households and community centers like rural schools (Safe Water Gardens, n.d.).

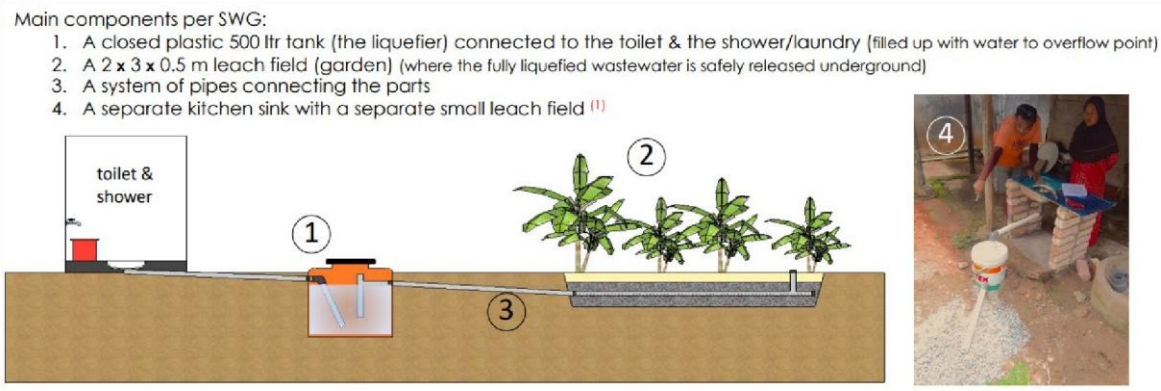

Figure 4. Safe Water Gardens model (Source: safewatergardens.org)

Approach

The digital topographical map of the affected area within the jurisdiction of Biratnagar Metropolitan City (BMC) was used to develop digital elevation model (DEM) by using geographical information system (GIS). The low-lying areas identified from the GIS indicated the flood prone area within the BMC. The potential

flood prone areas were sorted for flood of various return periods. The areas that were covered by annual flood was overlaid with the map of settlement areas. The combination of the flood hazard area and settlement area provided the flood hazard level and exposure level.

The demographic data from the BMC was used to map the vulnerability of the settlements within the high flood hazard areas. One of the highly vulnerable areas was Singhiya settlements along the Singhiya River in Ward No. 19 of the BMC, due to the informal nature of the settlement, lack of citizenship of the settlers, low-income level and challenges to the access to public resources.

A field visit was made to find the ground realities of the Singhiya settlement. The location and elevation of the household handpump and toilet-septic tank was noted during the field visit. To properly address the flood disaster induced WASH factors we plan to use GIS to map the (a) location of settlements in flood disaster hazard zone in Biratnagar, (b) locate potential areas for temporary refuge during flood inundation, (c) determine the minimum elevation of the toilets and taps to minimize water contamination during flood inundation.

Results and Discussion

The Singhiya settlers, who were born and raised in the same area, have demanded that their problem be solved, however, the local government has not responded to this issue, mainly due to lack of citizenship of the settlers. The informal settlers play an important role in the daily functioning of the metropolitan city; many of them take the day job and provide various services locally.

It was evident from the field visit that the physical distance of the handpumps used to extract water for domestic use and the septic tank was unacceptably low. In many households, the septic tanks have effectively turned into unmanaged cesspools. The black water was recharging the groundwater which was withdrawn through the handpumps. The local Singhiya residents could not afford to treat the water before using it for daily domestic purpose, posing a high threat to the sanitation system and their health.

Discussion with the concerned officials at the BMC revealed that the officials are aware of the situation but are unable to alleviate the situation due to the administrative, political and legal issues. Since the Singhiya settlers do not have citizenship certificate, they cannot purchase land, even if they can afford financially, which has forced them to settle in the flood prone high hazard public land. The lack of land ownership has dissuaded them from investing in better sanitation system. As non-citizens their name is not in the voter list, which has discouraged the local politicians in taking interest in solving their problem. The local administration finds it challenging to allocate budget to deal with the issues of unregistered informal settlements.

A study of the details of the SWG technology in Indonesia indicated that the technology can be adapted to different context. This study envisions the adoption of SWG technology for the Singhiya settlements in the BMC. A technical design for the household level decentralized WASH system similar to the one developed and implemented in Indonesia was adapted and modified for the site-specific conditions of Singhiya settlements. Waste water from toilet system and other grey water from household washing

including washing clothes flow into the tank and the mixing takes place. Nutrient rich water flows to the drain field where plants get their food and the water drips into the soil.

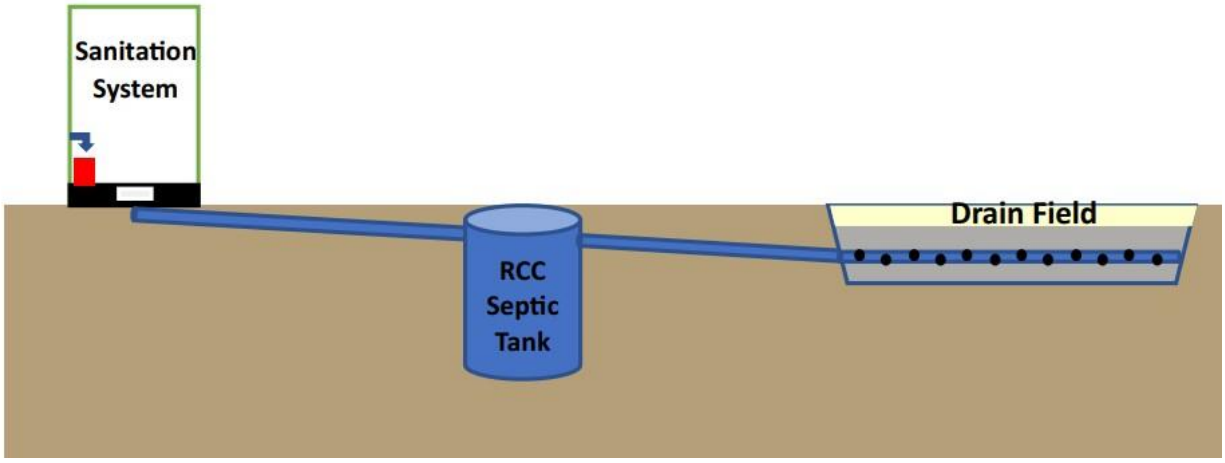

Figure 5. Proposed WASH model

The inundation and contamination of the water sources problem can be solved by preventing contamination of water sources during flood and inundation by measuring elevation for installing this system. Thus, decentralised WASH system is expected to (i) facilitate disaster prevention (mitigate water borne epidemics), (ii) prepare the community for flood events, (iii) increase the community's flood disaster resiliency and assist them in disaster recovery, (iv) enhance adaptation capacity of the community against climate change related flood disaster.

Conclusion

United Nations' Sustainable Development Goal No. 6 aims to ensure availability and sustainable management of water and sanitation for all worldwide by 2030. However, we see many issues in the ground level including for informal settlers in Singhiya riverbank of Biratnagar Municipality Council, Nepal. Every year, they go through the same issues and results in suffering from water-borne diseases. When the issue is persistent and exposed to contaminated water, it will result in weaken residents' health, making them more vulnerable to infections. Although access to safe drinking water is a fundamental human right, because of their status of being informal settlers, the local governments do not prioritise to solve this issue for them. This study investigated the possible solutions for given situation in the area and proposed technical design of a viable solution of decentralized WASH system.

Acknowledgment

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From Idle to Ideal: Urban Transforming Initiatives through Harnessing Agrivoltaics Symbiosis for Agricultural Revitalization

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Abstract

This study examines the challenges and opportunities presented by the Guandu Plain, situated near the heart of Taipei City, which has long awaited comprehensive development. The area faces significant issues due to the abandonment of agricultural land, prompted by the loss of the local farming population. This has led to the proliferation of urban waste disposal, illegal factories, and parking lots, encroaching on valuable agricultural spaces, and shifting maintenance costs to the remaining farmlands. The Guandu Plain is crucial in regulating the local microclimate and preserving regional ecological diversity. However, its potential is threatened by land pollution and the prospect of development-induced land use changes.

Addressing the complexities of land ownership, conflicting development expectations, and the fragmentation of agricultural land, this paper proposes a novel approach through a small-scale experimental initiative. The initiative focuses on agro-electricity symbiosis and the strategic exchange of public and private lands. This method aims to revitalize unused agricultural areas in alignment with sustainable ecological policies while leveraging solar energy infrastructure. Such infrastructure not only promises a stable supply of clean energy but also offers supplemental income for the agricultural sector. By adopting a compromise model, the initiative seeks to prevent land degradation and abandonment without compromising the landscape or agricultural productivity.

***Keywords**: Agrivoltaics Symbiosis, Renewable Energy Application, Land Use Exchange Strategy, Urban Transforming Initiatives*

The proposed initiative in the Guandu Plain closely aligns with several SDGs, notably:

SDG 7 (Affordable and Clean Energy), particularly target 7.2, which aims to increase substantially the share of renewable energy in the global energy mix.
SDG 11 (Sustainable Cities and Communities), with an emphasis on target 11.3 to enhance inclusive and sustainable urbanization and target 11.7 to provide universal access to safe, inclusive, and accessible green and public spaces.
SDG 15 (Life on Land) focuses on target 15.3, which seeks to combat desertification, restore degraded land and soil, including land affected by desertification, drought, and floods, and strive to achieve a land degradation-neutral world.

This article exemplifies how local agricultural revitalization and sustainable energy production can contribute to broader goals of sustainable livelihoods, directly addressing the conference's theme "Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood." By integrating agro-electricity symbiosis, this approach not only mitigates land degradation and supports agricultural

communities but also fosters resilience against climate change impacts. It demonstrates a practical model for linking terrestrial (mountain) and aquatic (ocean) ecosystems through sustainable practices that benefit both environments. This case study serves as a microcosm of how localized efforts can contribute to global sustainability objectives, highlighting the importance of innovative land use and energy solutions in rescuing the SDGs by 2030 for a sustainable future.

Research Background and Question

Due to the intensification of climate change in recent years, the increasingly evident threats to development prompted the Intergovernmental Panel on Climate Change (IPCC) to release a special report in 2018. To limit global warming to 1.5 degrees Celsius, global carbon emissions need to be halved by 2030 and reach net zero by 2050. Achieving net zero carbon emissions by 2050 has become a global common vision. If a company's carbon emissions are below the stipulated value or through supporting programs to reduce greenhouse gas emissions (such as protecting ecological green spaces with carbon sequestration capabilities), the surplus carbon emissions can be converted into "carbon credits" that can be traded on the market. Thus, "zero carbon" has become an important factor in joining international competitiveness and supply chains.

Taiwan is at a crucial stage of transitioning to net zero. To achieve the goal of net zero emissions, Taipei City has formulated an agricultural policy white paper, and civil groups like "Carbon Uptake by Public Property" have proposed initiatives such as the Guandu Carbon Reduction Platform, dedicated to accelerating the net zero process by matching public land resources with carbon reduction measures. The Guandu area, as a large green space within Taipei City, is rich in agricultural ecology, hydrology, wetlands, mangroves, and vegetation, possessing a substantial carbon sequestration capacity. This gives it a unique potential as a natural carbon sink for sustainable urban transition. We aim to align these objectives with agrivoltaic systems, using agricultural resources as a foundation, complemented by solar power to promote community energy self-sufficiency, establishing agricultural education demonstration areas to enhance the quality and competitiveness of agricultural products, and achieving the implementation of a positive energy community.

The stakeholders in the Guandu area have conflicting and interrelated interests, and the existing legal frameworks and regulations have not been able to address the associated challenges. To reconcile these contradictions and promote local momentum, we propose the "Integrated Positive Energy Community Agrivoltaic Coexistence Plan." This plan aims to explore the feasibility analysis and experimentation of implementing agrivoltaic coexistence in the Guandu area, and to utilize the current status of public and private agricultural land for the most advantageous land exchange strategies for agrivoltaic coexistence. This plan not only responds to the Paris Agreement on an international scale but also incorporates the spirit of the Satoyama Initiative to practice the concept of sustainable development. Using small-scale projects as a fulcrum, we attempt to derive different possibilities, communicate future visions with cases and images, and develop solutions acceptable to various stakeholders

Introduction of Guandu Plain

Diverse Expectations for Land Use in Guandu Plain

The Guandu Plain is an extensive urban planning agricultural area within Taipei City, covering about 540 hectares, which accounts for approximately 90% of the planned agricultural land in the city. It has not

been subject to development arrangements as an urban planning area. The vast green space not only has a cooling island effect on the microclimate of the Taipei Basin, but it is the preservation and blank space for agriculture and ecology that allows Taipei's urban transformation to more effectively address current climate resilience and net zero carbon emission sustainability issues. This land use, which already bears different expectations, has led to discussions from various perspectives.

In the 1980s, Taipei City intended to develop the Guandu Plain further. Ultimately, due to considerations for wetland conservation and overall urban development, the city government adopted a low-density development model, preserving this vast plain. Regardless of past plans, the unique location of the Guandu Plain has led successive city governments and development teams to hope to "make good use of" this expansive open land. Subsequent mayors of Taipei City have all conducted development planning for the Guandu Plain, though most plans have remained just that—plans.

For the landowners of the Guandu Plain, local development faces rigid zoning controls, a lack of appropriate agricultural infrastructure such as farm roads and irrigation channels, and insufficient incentives for active investment. As a result, much of the agricultural land is temporarily used, with many landowners renting or selling the land for other uses or choosing to leave it idle, waiting for future development plans. Without effective guidance and with landowners lacking the willingness to manage the land, many factories, warehouses, parking lots, and scattered non-agricultural facilities have spread into these agricultural areas. This not only fragments the initially integrated land use but also deteriorates the condition of good farmland.

In the process of modern industrialization and modernization, various environmental issues have emerged, gradually threatening human survival and development. Spaargaren and Mol (1992) pointed out that environmental problems are seen as products of modernity, closely related to modern society.

This has drawn increasing attention from sociologists, who not only attempt to understand the fundamental characteristics of modern society but also realize that to address these issues, it is necessary to adjust the cultural, political, and economic systems of contemporary society on different levels. In other words, the relationship between environmental issues and modern society is becoming a driving force for social change. In industrialized countries, "sustainable development" has become a key concept for overcoming ecological and environmental crises. On one hand, because the concept of sustainable development does not have clearly defined boundaries, it allows for multiple interpretive perspectives. On the other hand, from the viewpoint of sustainable development, ecological environmental protection and economic growth can be compatible and mutually reinforcing, thus becoming a common environmental governance trend in both developing and developed countries. In the current issue of urban sustainable development, stakeholders concerned with the conservation of ecological and agricultural environments are beginning to receive policy planning attention, opening a new chapter with sustainable urban governance discourse.

Overview of Current Land Use in Guandu Plain

The agricultural activities in Guandu are embedded in the evolution of urban governance and the operation of social networks, triggering a series of planning, institutional, strategic, and action responses

through a dynamic interaction of interdisciplinary knowledge and values, forming the positioning of urban agriculture (Jian, 2023). In recent policies, the Guandu Plain has been transformed from an agricultural development area and a national reserve area to an urban-rural development area, lacking a clear development position. However, due to its locational advantages, land speculators have speculated that it is "urban development reserve land." This has hindered proper agricultural use.

The Guandu Plain mainly produces rice, and even though much of the farmland is idle, there are still 170 hectares of rice cultivation area (Jian, 2023). The agricultural land is vast, but the current usage can be roughly divided into three issues:

The overall planning for Guandu is not clear, and the plans of successive mayors vary, making the already complex agricultural land management situation even more lacking in transformation motivation.

Landowners mostly idle or lease the land without contracts to substitute farmers, anticipating land acquisition and urban development plans, worrying that renting out the land might exclude them from acquisition plans.

The fragmented land, complex property rights, and lack of agricultural infrastructure make it difficult for the local farming population to expand the scale of economy and production, resulting in low agricultural economic benefits. They choose to leave the land idle or convert it to other uses.

These phenomena lead to an increasing number of idle or contract-less leased farmlands. The land owned by landowners more often serves as reserve land for urban transformation, waiting for value appreciation after land acquisition or development implementation, ultimately making the Guandu Plain largely passive and awaiting development. Due to the lack of friendly participation thresholds, farmers who wish to invest in Guandu agriculture are discouraged.

Under the premise of unclear land policies, the core goal of the Satoyama Initiative is to provide clear paths for sustainable urban governance and strategic guidance. The Satoyama Initiative emphasizes promoting and supporting socio-ecological production landscapes. Due to the sharp decline and aging of the rural population, many socio-ecological production landscapes have been abandoned (Li Guangzhong, 2011a). At the same time, existing ecosystems are impacted by pressures from unplanned urbanization, industrial development expectations, and other factors. Therefore, by establishing databases, developing research methods, constructing measurable indicators, and disseminating information broadly, we can actively intervene in rural areas to prevent the continuation of the abandonment problem. Although the complexity of urban agricultural land policies and the factors leading to land abandonment are not entirely the same as in rural contexts, this study's action strategy can supplement sustainable urban transition, encourage local agricultural production, and experiment with agrivoltaic education fields, in line with the experimental framework of the Satoyama Initiative, exploring the diverse benefits of urban agricultural land.

Environmental Impact of Informal Land Use

Due to a lack of consensus on development and the changing governance attitudes of city governments every few years, some landowners lease their land to others for cultivation, convert it to taxi parking lots

or waste disposal sites, or leave it idle. These states cause the cost of living in prime urban areas to be easily transferred to the cheaper and less managed Guandu Plain. This idle and unmanaged, development-awaiting state itself poses many unpredictable damages: unmanaged idle land is dumped with waste soil; agricultural land used for parking lots and waste treatment sites makes it difficult to ensure soil quality; illegal factories take advantage of the situation to rent Guandu land, claiming to enhance the land use efficiency. The idle and neglected urban agricultural land not only fails to provide the agricultural ecological diversity function but may also damage the existing ecological diversity of Guandu.

Social-ecological system interactions in agricultural landscapes often produce agricultural ecosystems with unique cultural values. These values, known as cultural ecosystem services (CES), include non-material benefits such as spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. CES is often underestimated, even in economic valuations, because they overlook the socio-cultural connections between people and the environment.

Research Methodology and Design

This study employs field investigations, stakeholder workshops, focus group feedback, and participatory action research to understand the various tensions and issues the Guandu Plain faces. After understanding the current situation, we use the DPSIR analytical framework to develop strategic simulation scenarios, iterating our analysis based on feedback to ultimately propose solutions.

The DPSIR Framework Assessment

We present the current situation through the DPSIR framework to analyze problems and the status quo, determining the actions and directions for data collection and experimentation:

- Drivers: The lack of consensus on land policies leads to local dissatisfaction with long-term idleness and nervousness about large-scale developments.
- Pressures: Developers and landowners actively seek land transition, and the city government has development expectations through various plans.
- State: Land is fragmented and idle, there is insufficient agricultural economic scale, the agricultural population continues to decline, and agricultural land is repurposed for other uses.
- Impacts: Government development expectations lead landowners to seek investment resale, increasing land prices and rents, reducing willingness to use land for agriculture, and repurposed land faces pollution risks.
- Responses: The government proposes new policies aiming to address issues faced by both the Guandu Plain and the city itself.

From this, it is evident that urban agricultural zone issues are complex and interlinked, recurring repeatedly. Through focus group discussions, feedback, and case analysis of different actions, we develop experimental schemes suitable for local conditions.

Focus Group Interview and Participatory Workshop

Workshops with small farmers, businesses, the Taipei Wild Bird Society, the Taipei Beautiful Rivers Promotion Association, the Homemakers United Foundation, lecturers, and students from Beitou

Community University was held to discuss the redevelopment of the Guandu Plain. We aimed to understand the responses and consensus of various stakeholders under the net-zero carbon framework. Through the discussion of experimental plans for agrivoltaics, we addressed the concerns of different stakeholders, providing feedback into the DPSIR framework for strategic adjustments.

Case Study

Homemakers United Foundation (HUF) - "干豆好 gàn dòu hǎo" Civic Power Plant: This project established a civic power plant on public buildings, testing the efficiency of photovoltaic installations and using it for community energy education. This case is valuable for its replicability and inspiration, showing that energy generation is not solely reliant on large-scale markets but can involve ordinary people (HUF, 2020). It also demonstrates the potential for public land facilities to provide energy education and community participation.

Pingtung Dashun Vanilla Production Cooperative: This case carefully calculates the economic benefits of species with lower sunlight requirements and solar panels to achieve true agrivoltaic integration. Although this project did not discuss landscape aesthetics, it expanded the possibility of coexistence, opening up opportunities for discussions on the aesthetics and harmony of energy landscapes.

International Cases: These include Japan's "small farmer-led" photovoltaic projects and Israel's diverse agrivoltaic experiments, showing the potential for flexible small-scale trials and emphasizing the importance of government policy support. These international examples demonstrate small-scale flexible trials led by local farmers and underscore the importance of government policy support.

Through real-world examples of agrivoltaics, we support an agriculture-based agrivoltaic mechanism, feeding back into our research strategy. Our research develops strategic proposals in response to the current land policy situation in the Guandu Plain, with small-scale experimental plans helping to avoid the impact of technological delays.

Output Simulated Action for DPSIR Re-assessment Analysis

We again use the DPSIR framework to analyze and predict the impacts of agrivoltaic strategies on the local area, refining experimental directions:

- Drivers: Aiming for net-zero and energy transition, focusing on improving agricultural production, increasing economic benefits, reducing environmental pollution, and lowering carbon emissions in the Guandu Plain to maintain and enhance agricultural and ecological environments.
- Pressures: Limitations of regulations and land resources, costs of photovoltaic and agricultural technologies and equipment, insufficient policy support, and low social awareness, with policies and developers actively seeking land.
- State: Assisting in improving land use efficiency, reducing agricultural carbon emissions and waste generation, increasing power supply stability, and enhancing agricultural production efficiency.

- Impacts: Reducing environmental pollution, reliance on traditional energy, risk of pollution on idle land, improving the local agricultural production environment, and increasing local economic benefits.
- Responses: Enhancing policy support, increasing social awareness, reducing technology and equipment costs, and conducting feasibility studies.

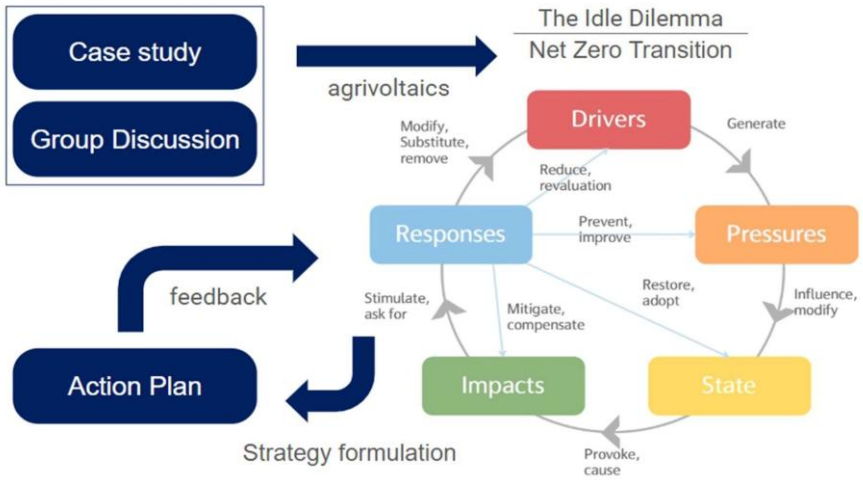

Figure 1. Output Simulated Action for DPSIR Re-assessment Analysis

By directly participating in discussions on land strategy plans for the Guandu Plain, we further obtained stakeholder suggestions and information to iterate and revise experimental plans. Ultimately, this study discusses strategies with agrivoltaics as the main theme.

Results and Discussion

To better meet the expectations of ecological conservation and land development in the Guandu area, this study aims to address the risk of degradation caused by idle farmland directly. It proposes a pilot project to delay and avoid a state of continuous degradation, and serves as a communication basis for subsequent land applications in line with urban sustainable transition policies.

Analysis of Issues and Land Restoration Directions

As mentioned in previous sections, unmanaged idle land is being used to dump waste soil. Agricultural land repurposed for parking lots and waste disposal sites makes it difficult to revert back to agricultural use. Illegal factories renting Guandu land emphasize the need to enhance land use efficiency. These are the primary issues of the Guandu Plain, including the government's unclear stance on urban agriculture and the lack of a clear vision. This not only makes it hard to maintain agricultural and cultural ecosystem services (CES) but also destroys the existing biodiversity in Guandu. Additionally, fragmented land and complex ownership make it difficult to effectively expand and develop agricultural production in the Guandu Plain. Although both government and private entities have attempted to introduce governance mechanisms, the complex ownership and usage status have hindered effective improvement. This study

proposes the "Agrivoltaics" solution, integrating solar energy with farming, to conduct sustainable policy experiments and land restoration, hoping to create more communication opportunities in the process.
The agrivoltaics concept in this study is based on Japan's combination of agriculture and solar power generation. It involves the installation of solar panels on farmland, with careful planning and calculation to expand the agricultural area under the panels while maintaining the agricultural function of the land. This approach can achieve multiple benefits, including providing clean energy, reducing dependence on traditional energy sources, protecting farmland, and promoting sustainable agricultural development. Through agrivoltaics' energy supply and utilization model, it helps combine solar power generation with agricultural production. The promotion of agrivoltaics in the Guandu area can parallel the installation of solar power systems with agricultural production and sales, strengthen the resilience of the local power grid, and support the expansion of local energy facilities, agricultural product distribution, and agricultural production activities. These actions and infrastructures are crucial for low-carbon, circular and self-sufficient operations in the region. This integrated energy-agriculture system helps improve energy use efficiency while protecting land resources and the environment. Our team encourages the participation of Guandu residents, increasing the community's energy self-sufficiency and economic benefits, which not only helps reduce dependence on traditional energy, but also promotes community participation and the development of a shared economy.

With the goal of "net-zero transition," the team proposes to designate a portion of the Guandu Plain as a demonstration site for Taipei City's net-zero transition, and to conduct carbon reduction and transition experiments at the levels of industry, natural carbon sinks, and positive energy communities.

Design and Land Utilization Considerations

Ensure that solar development does not harm the surrounding landscape and ecosystem. Promote local opinion participation and benefit-sharing. Achieve maximum spatial co-use and land recoverability post-decommissioning.

Guidelines:

- Three Musts:
  - Utilize space in a composite manner.
  - Ensure land returns to its original state post-decommissioning.
  - Respect local residents and communicate with the community from the initial site selection stage.
- Three Don'ts:
  - Do not affect existing ecosystem service functions.
  - Do not destroy visual landscapes and cultural assets.
  - Do not sacrifice local life and well-being.

Since 2000, Taiwan has promoted solar photovoltaic technology, but its growth in installation has not met expectations until the policy drive for energy transition and net-zero carbon emission targets in 2017. Under the pressure of national policies and the timeline for net-zero goals, a large amount of agricultural land has been rapidly converted for solar power projects. The previously slow development caused the rapid advancement of solar policies to fail to respond to the ecological impact risks between farmland and solar land use, and technological delays impeded the development of other feasible compromise solutions, maintaining a backward learning attitude. Accelerating the development of the industry will expand the technology-society

gap, leading to unrecognized risk mechanisms and communication capabilities (Chou, 2000). Additionally, since 2017, the rapid development of solar power has drastically changed agricultural landscapes, causing significant ecological and agricultural impacts. Experts, scholars, and farmers have expressed concerns and opposition. In the absence of effective and credible environmental assessment mechanisms, most solar projects develop wherever land is available, striving to meet policy goals and maximize business interests, resulting in a lack of trust in the solar industry in Taiwanese society.

This experimental plan proactively addresses four design considerations to eliminate past doubts:

- Landscape: Solar power should integrate with the surrounding natural landscape, with green belts and hedges set according to the integrated planning principles, enhancing aesthetics and emphasizing habitat creation and increasing carbon sequestration through soil conservation.
- Ecosystems: The integrated planning aims to enhance the site's environmental quality, ecosystem functions, and biodiversity conservation. Healthy ecosystem services will directly benefit local agriculture and public welfare.
- Local Community: Solar development should prioritize and respond to stakeholder needs. Integrated planning emphasizes local participation, incorporating community opinions into design schemes to establish a trusting and shared partnership with the community.
- Spatial Co-use: The spirit of integration is to share space with original land users as much as possible. Through innovative design, promote spatial co-use and avoid land resource competition.

Public and Private Land Integration and Exchange Plan

We propose the "Integrated Positive Energy Community Agrivoltaic Practice Plan" trial project, which aims to protect the ecology while responding to the needs of urban transformation. By promoting agrivoltaics, we aim to integrate scientific monitoring and ecological management methods to ensure the stability of the ecosystem and protect the value of farmland in the Guandu area. This project will also actively guide development actions to comply with ecological conservation principles, avoiding environmental damage and resource waste. Our goal is to establish a sustainable Guandu area that protects valuable ecological resources while creating opportunities for community development and prosperity. This trial project will achieve a green and net-zero transition for the Guandu area, providing a better living environment for future generations.

Key Concepts: Satoyama Initiative, Citizen Power Plant, Creating Inclusive Photovoltaics.

Building on the previous discussions, our "Integrated Positive Energy Community Agrivoltaic Practice Plan" further explores and develops the Guandu area. In addition to adhering to national regulations and related policies, we will also focus on key concepts such as the Satoyama Initiative, citizen power plants, and symbiotic solar energy to enhance the effectiveness and sustainability of the plan.

Firstly, the Satoyama Initiative aims to protect and revitalize mountain resources, incorporating them into community development (Li Guangzhong, 2011 & 2016). In our plan, we have observed the ecological impact caused by idle and abandoned farmland. Therefore, protecting and effectively using the land resources in the Guandu area will reduce the risk of environmental destruction, with agrivoltaics as the core solution for a positive energy base. By respecting the natural environment and conserving ecosystems, we strive to achieve harmonious agriculture, energy, and ecology development, avoiding other damages caused by land idleness.

Secondly, a citizen power plant is a community-driven and operated energy generation facility. In our plan, we will encourage residents of the Guandu area to participate in constructing and operating citizen power plants, increasing the community's energy self-sufficiency and economic benefits. This helps reduce dependence on traditional energy sources and promotes community involvement and the development of a sharing economy.

Lastly, creating inclusive photovoltaics is an energy supply and utilization model that combines solar power generation with agricultural production. Promoting the concept of symbiotic solar energy in the Guandu area can integrate solar power facilities with farmland production and sales, enhancing the resilience of the local power grid while supporting local energy, agricultural product distribution, and agricultural production activities. These actions can all be operated autonomously in the region under a low-carbon cycle. This integrated energy-agriculture system helps improve energy utilization efficiency and protects farmland resources and the environment.

Integrated Public and Private Land Exchange Plan.

We propose utilizing public and private land exchanges based on the aforementioned three concepts. The aim is to swap privately abandoned farmland with public good farmland, allowing parts of the abandoned private land to be used for agricultural infrastructure and agrivoltaic purposes. This gives abandoned farmland a chance to be restored for agricultural use. After exchanging public good farmland with private land, the public and private sectors can collaborate to maintain the land's agricultural use and jointly develop and assess the feasibility of agrivoltaics. The final land utilization scenarios will be:

- Public good farmland ←→ Private abandoned land
- Private good farmland ←→ Public abandoned land
- Private Agrivoltaics maintaining farming ←→ Public agrivoltaics on good farmland + Public agricultural infrastructure

The placement of photovoltaic facilities will transition from sparse to dense, from private to public, and from farmland to buildings. This ensures that energy landscapes are not overly intrusive or poorly planned. Public sector-led agrivoltaic installations will actively ensure that photovoltaic equipment is centered on agriculture without replacing agricultural land proportions, truly implementing policy needs in a demonstrative manner.

Figure 2. Strategy of Urban design

The same land exchange concept can also be applied to the wetland park in the Guandu Plain, expanding the wetland area and increasing wetland ecological habitats in the region. This strategy serves as a medium for observing the complexity of land use changes and provides more opportunities to engage with different landowners and stakeholders. Public sector strategies will demonstrate the goals and determination of the net-zero transition, helping to establish a platform for multi-stakeholder coordination.

Sustainable Development Policies and SDGs Goals

The "Integrated Positive Energy Community Agrivoltaic Practice Plan" can guide agrivoltaic practices, showcasing the potential to land management authorities and responding to national regulations promoting net-zero policies. We will address regulatory expectations by implementing the following:

- Just Transition: We will uphold the just transition principles by utilizing climate funds to support the project's implementation, ensuring community participation and shared benefits (Fair Transition §5).
- Community-Based Adaptation: We will adopt community-based adaptation measures to ensure residents can participate in and benefit from the agrivoltaic plan, providing environmental education to enhance their understanding of net-zero emissions and renewable energy (Community-Based Adaptation §25, Environmental Education §45).

Activation of Idle Public Land: We will actively promote the revitalization of idle public land for renewable energy projects, such as solar panels, small hydropower, or wind power facilities, maximizing land resources and achieving sustainable energy development (Activation of Idle Public Land §38).
In return for community residents' participation and support, we will offer economic incentives under municipal reward or subsidy policies, encouraging active involvement in the agrivoltaic plan and sharing the economic benefits of green energy (Municipal Rewards or Subsidies §40). Finally, we will implement carbon offset programs to compensate for carbon emissions, further promoting the goal of net-zero emissions.

SDGs 9, 11, & 15 Objectives Explained

- SDG 9 (Industry, Innovation, and Infrastructure): Our plan focuses on developing power and agricultural infrastructure with innovation in land use and strategic exchanges. This approach strengthens local energy resilience while installing agricultural infrastructure under the agrivoltaic (agriPV) framework. By addressing the long-standing lack of agricultural infrastructure in the Guandu Plain, we can enhance local farmland productivity and convenience, preventing the excessive displacement of agriculture by photovoltaics in the agrivoltaic strategy. The adjustment of farming practices due to agrivoltaic systems will be complemented by photovoltaic income, providing continuous incentives for farming and promoting various agricultural advantages.
- SDG 11 (Sustainable Cities and Communities): The plan's implementation is based on the sustainable resource needs of urban areas, catering to land development changes, continued agricultural use, and ecological diversity. The experimental plan emphasizes regional cooperation through established discussion mechanisms, focusing on agriculture and regional energy, and creating cooperatives for production, sales, and power to enhance community communication platforms and cooperative awareness.

- SDG 15 (Life on Land): The plan prioritizes targeting abandoned farmland to avoid increased pollution risks to the ecosystem. By restoring agricultural use and guiding the installation of agrivoltaic systems (agriPV), we aim to improve the ecological environment and promote ecological conservation through supportive agricultural practices. The agrivoltaic framework will incorporate equipment, planning, design, and reward policies to enhance terrestrial ecosystems.

Cross-Regional Sustainability Goals: SDGs 7 & 13

- SDG 7 (Affordable and Clean Energy): The experimental plan aims to facilitate stakeholder communication and coordination, ensuring energy security while aligning with sustainable urban development policies. By utilizing abandoned land in the Guandu Plain, we will expand photovoltaic energy infrastructure and improve agricultural production efficiency, laying the groundwork for the global shared renewable energy goal.
- SDG 13 (Climate Action): The plan advocates and responds to national and urban climate policies, constructing regional urban food self-sufficiency, restoring abandoned farmland, expanding ecosystems, and enhancing disaster resilience and climate adaptation capacity. The Guandu Plain will serve as a turning point for urban policy, providing guidance and demonstration for regional climate resilience.
- Effectiveness Evaluation of Multiple Land Restoration Strategies
- The experimental plan will increase societal awareness of agrivoltaics and land restoration practices, attracting more landowners willing to reconsider land use and gradually restoring previously damaged lands. Through land exchange and agrivoltaic experiments, we aim to leave healthy land for sustainable transition, regional energy security, food security, and biodiversity. Additionally, this will create numerous environmental education sites.

Contributions and Insights for Sustainable Development

The experimental plan aims to contribute to biodiversity, regional food security, and microclimate regulation, steering the Guandu Plain away from the risks of continued abandonment or intensive urban development. Agrivoltaics not only prioritize agriculture, with photovoltaics supplementing farming income, but also limit large-scale construction. A successful experimental plan will demonstrate a path for restoring abandoned land through urban agriculture. Enriching the Guandu Plain's advantageous agricultural and ecological diversity is essential without a clear development consensus.
Taipei City's Guandu Plain exemplifies the lack of consensus among landowners, conservation groups, and the government. We can restore abandoned land and configure agrivoltaic facilities through policy tools, transforming deteriorating land and increasing agricultural land. The generated electricity will stabilize regional energy, supporting agricultural energy self-sufficiency.

Recommendations

The "Integrated Positive Energy Community Agrivoltaic Practice Plan" in the Guandu area of Taipei is a strategic approach that not only facilitates a transition to net-zero emissions and increases agricultural productivity but also reduces environmental pollution and carbon emissions, enhances local economic benefits, improves community living standards, and boosts farmers' incomes. By setting up land policy mechanisms, this plan can increase landowners' responsibility and motivation for land use. Government

intervention can better maintain the integration of agriculture and photovoltaics, avoiding past issues where private initiatives to install solar panels damaged land. This plan thus aligns with relevant laws, regulations, policies, and local support.

Recommendations for Future Development

- Strengthen Policy Support: Governments and relevant agencies should actively promote this plan and provide necessary resources and support, including financial aid, technical assistance, and training, to ensure the plan's successful implementation.
- Increase Social Awareness: Conduct environmental education and publicity activities to raise community residents' awareness and understanding of net-zero emissions and renewable energy, encouraging them to participate actively in the agrivoltaic plan.
- Conduct Feasibility Studies: Evaluate the feasibility of land resources, technical costs, and economic benefits, and adjust and improve the plan based on research findings to ensure sustainable development.
- Monitoring and Evaluation: Regularly assess and monitor the plan's implementation, making adjustments and improvements as needed to ensure feasibility and sustainability.
- Urban Design Guidelines: Develop guidelines for land exchange principles, agrivoltaic installation proportions, and agricultural infrastructure design standards, building density, and maintaining agricultural output ratios.

By combining these efforts, the plan can promote sustainable development, enhance local economic benefits, improve community living standards, and support farmers, ultimately contributing to the overall well-being and sustainability of the Guandu area.

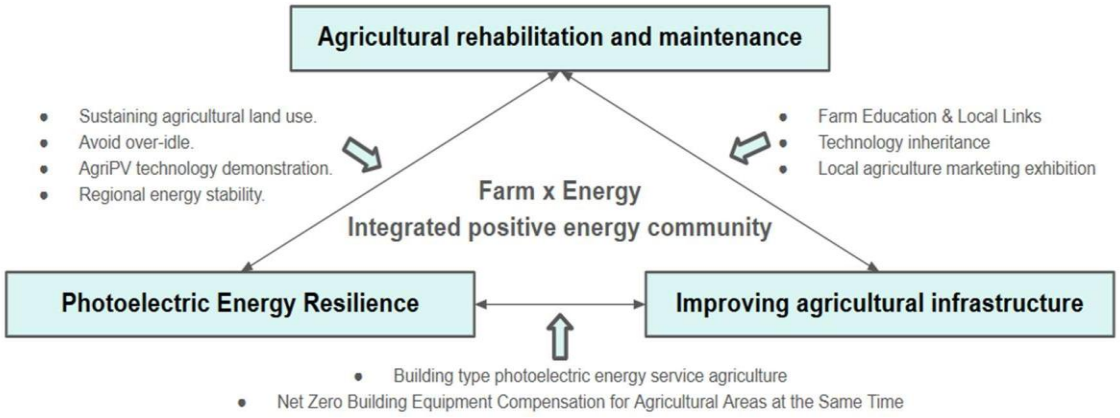

Figure 3. Integrated positive energy community

Insights for Local Policies and Practices

Although agrivoltaics (agriPV) ideally addresses the research issues, it may not gain full support from farmland protection advocates. Urban agriculture in the Guandu Plain faces the challenge of unclear future directions. If local groups do not actively maintain and engage in this policy-driven land use plan, it might become a precursor to large-scale development. Without a clear commitment to agriculture, the experimental plan risks loosening usage restrictions, converting agricultural land to construction land, and losing farmland.

This plan highly relies on clear policy guidance and continued labor force investment interested in sustainable urban agriculture. To break the cycle of mistrust, the experimental plan must first address "illegal use," "waste pollution," and "long-term abandonment" through coordination, enabling the restoration of idle land.

Conclusion

This article explores the challenges and opportunities of land use in the Guandu Plain, Taipei City, and proposes the "Integrated Positive Energy Community Agrivoltaic Practice Plan" centered on agrivoltaics. The plan aims to revitalize idle agricultural land and promote sustainable ecological policies through small-scale experimental measures and strategic public-private land exchanges. Agrivoltaics provide a stable supply of clean energy and offer additional income for the agricultural sector while protecting land resources and the environment. The plan seeks to reduce land degradation, enhance agricultural production efficiency, and boost local economic benefits. Ultimately, the study outlines various strategies and recommendations to achieve sustainable development goals in the Guandu area, emphasizing the importance of collaboration among the government, community, and stakeholders for the plan's success.

Acknowledgment

The authors wish to thank all the research participants, without whom, this work would not have been possible. The authors would like to acknowledge the financial support of the Ministry of Science and Technology (MOST), Taiwan, under the grant number MOST 111-2621-M-002-008.

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Posters

Submission ID: 226

Potential Climate Benefits of a Bio-Based Built Environment with Regionalised Supply and Demand

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Abstract

The built environment contributes more than a third of global energy-related carbon emissions. This trend is expected to grow with rapid urbanisation and rising demand for fossil-based construction materials (UNEP 2023). In order to meet global climate targets, the sector needs to reverse its emission trajectories. One way of achieving this is to shift construction material input from carbon-intensive materials, such as concrete and steel, to bio-based regenerative products including timber and bamboo, which have the potential to store significant amounts of carbon in the long term.

The transition towards a net-zero built environment could be further advanced if materials are sourced from regional forests, considering the growing interest in 'regionalising' or 'shortening' supply chains to promote self-sufficiency and reduce climate impacts. We therefore propose a model to systematically quantify and match the supply of and demand for bio-based building materials for all urban agglomerates globally. A key feature of the model is to be spatially explicit, thus exploring the potential for demand to be met by regional supplies.

The model is divided into the following components: on the supply side, it will use a statistical model to map potential timber production. In terms of demand, the model will use high-resolution earth observation datasets to quantify building typologies and thus material demand for urban agglomerates. Future demand will be projected by considering various scenarios of socio-economic development, particularly with regards to future developments of floor area, distribution of building typologies, and the level of adoption of bio-based building materials. To match supply and demand, a spatially explicit supply-demand balance algorithm will be applied to identify regional forest areas needed to theoretically supply future urban construction materials. Finally, the model will quantify carbon sinks and substitution effects of a bio-based built environment using life-cycle assessment (LCA) approaches.

The model's findings could demonstrate how the built environment can play a leading role in mitigating climate change and thus reducing its impacts on climate-sensitive environments. Our model has clear relevance for SDG 9, in particular for Target 9.4 in promoting the use of "clean and environmentally sound technologies and industrial processes" through the widespread adoption of bio-based materials. Through its regionalised approach, our model could also inform national and regional development planning in supporting positive economic, social, and environmental links between urban and rural areas (SDG 11, Target 11.a), as we seek to investigate the potential of bio-based materials being supplied locally. Finally, the model's carbon quantification estimates could inform national policies, strategies, and planning on climate mitigation (SDG 13, Target 13.2).

6b. Urban and Regional Resilience

Abstracts

Submission ID: 18

Future Conscious Water Policy, Governance and Usage of Local Communities in the EU

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Abstract

Water is a paradox: it is a seemingly abundant and renewable resource, while only a tiny amount of it is accessible and drinkable. Global water resources are unevenly distributed and many of them have been contaminated.

"Water is our most precious resource, a 'blue gold' to which more than 2 billion people do not have direct access. It is not only is essential to survival, but also plays a sanitary, social and cultural role at the heart of human societies." (Audrey Azoulay, UNESCO Director, 2021)

The existence of life is inconceivable without water. Water is an essential pre-requisite for existence and sustenance of life in any form. The natural resources - be it in the form of safe drinking water, targeted both in the UN Millennium Development Goals (MDGs, Goal 7) and in the UN Sustainable Development Goals (SDGs, Goal 6) - are public goods. Water is an international public good and is associated with common pool resources (CPR) and collective action problems whose solution calls for international cooperation and action. The extreme and rapid changes in our climate, have severe environmental consequences, long droughts in one place, and sudden floods in others, with increasing number of water-scarce areas in the world.

It is very important that we should learn lessons from our ancestors and draw important conclusions for our own future. Technology and perfect engineering are not enough: local communities, both urban and rural, need to be careful with their water resources, manage and govern them wisely, in a future-conscious way, paying attention to socio-cultural factors (related to UN SDG 11 and the conference topic) as well. Well-developed ancient civilizations have disappeared because of human environmental degradation, bad resource management and related socio-political problems.

The paper is focusing on the comparative analysis of smart local/regional water usage, governance models and community initiatives – with special attention to the socio-cultural factors - within the EU water policy framework.

Submission ID: 29

Beyond Borders: A Comparative Exploration of Seismic Design Standards in Germany and Iran

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Abstract

In the face of escalating global ecological crises, sustainability has emerged as a critical imperative to address the substantial environmental impact of various sectors. One significant driver of global resource consumption is the construction industry, with a heightened focus on sustainable building design. However, this commitment to sustainability encounters conflicting goals, particularly in earthquake-prone areas, where the imperative for seismic resilience necessitates a certain material investment that challenges the principles of sustainability and resource efficiency. Different countries, each characterized by unique geographical conditions, impose varying requirements on seismic building design. Against the backdrop of seeking generalizability and/or transferability of methods to determine sustainable material use while ensuring resilience to geotectonic environmental risks like earthquakes, notably prevalent in mountainous regions or regions with tectonic plate boundaries, a crucial aspect is to examine the implementation within region-specific building codes.

In our contribution, we present a comparative analysis of normative seismic design regulations between Germany, located in a region with lower earthquake vulnerability in Europe, and Iran, characterized by mountainous terrain in Asia with numerous faults and a high seismic risk. The building code acts as a bridge between hazard research findings and the impacts or requirements for structures. It involves determining relevant parameters and their effects on the structural design, necessary load-bearing capacity, and usability of individual components, considering the entire building. Our comparative study on the Iranian seismic design standard "Standard 2800" and the "DIN EN 1998 (Eurocode 8 with the National Annex for Germany)," governing seismic design in Germany and the EU, provides a concise overview of key content and compares pivotal parameters of seismic design. The analysis includes seismic zones characterizing the impact, subsoil types crucial for earthquake wave transmission and damping, and the importance factor characterizing the societal significance of buildings as a measure of the impact on residents. The comparison of standards reveals some similarities but also differences. For instance, both codes define social significance in the same way. Nevertheless, the geological boundary conditions and, consequently, the degree to which the population is affected differ significantly. This contrast is ultimately manifested in these codes, among other factors, through distinct approaches to design parameters for planning resilient buildings in both countries.

Submission ID: 48

Exploring Challenges in Implementing Community-based Disaster Risk Management (CBDRM) Framework at the Grassroots Level: A Theoretical Study

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Abstract

Frameworks serve as conceptual and operational blueprints that help in the systematic planning, implementation, and evaluation of certain activities. They offer a structured approach to understanding the complexities involved and provide guidelines for effective practice. Community-based Disaster Risk Management (CBDRM) is a participatory approach that engages vulnerable communities in disaster risk reduction (DRR) activities. Several frameworks have been formulated to aid in operationalisation of CBDRM in the ground. The purpose of this study is to explore the challenges and gaps in implementing these CBDRM frameworks at grassroot level for the vulnerable communities that are exposed to different kinds of hazards. The research aims to conduct a systematic literature review to assess the existing frameworks in CBDRM. Thus, a two-pronged literature research was conducted. Firstly, we identified existing CBDRM frameworks from various geographies. Next, we identified CBDRM implementation case studies. Web of Science and Scopus databases were used for both the searches. We analysed each framework's key features, strengths, and challenges. The identified CBDRM frameworks address topics like public participation, risk reduction, policy, governance, and disaster preparedness in a generic way, lacking specific community-level details, step-by-step implementation guidelines, and a focused approach on vulnerable demographic groups. Establishing a universally effective CBDRM framework is challenging due to the unique characteristics of each global community, requiring customization to cater to the specific needs and conditions of vulnerable populations. The search was done using Web of science and Scopus through a systematic literature reviews as primary methodology. This includes an analysis of 39 case studies and frameworks adhering to the implementation of Community-based Disaster Risk Management at grassroot level. The paper has thoroughly scrutinised the CBDRM framework and its grassroots application, examining their scope, objectives, approach, strengths, challenges, and gap. The study acknowledges constraints in its thorough examination of 39 case studies, indicating that the utilization of these frameworks is lacking practical implication at the grassroots level, for vulnerable communities that are exposed to different kinds of hazards. These gaps highlight the shortcoming of CBDRM framework that do not adhere to the vulnerable communities at the grassroot level.

The study's results indicate that numerous CBDRM frameworks do not effectively contribute to enhancing resilience at the grassroots level for vulnerable communities. Frameworks failing to fulfil their intended purpose become ineffective. The existing frameworks demonstrate substantial shortcomings, incapable of addressing the diverse geographical needs of each vulnerable community. The study's significance lies in recognizing the gaps and challenge of an effective CBDRM framework, emphasizing that they do not serve the purpose to vulnerabilities communities with diverse culture and traditions. It ensures the future reserarch work for relevant CBDRM framework in evolving disaster scenarios. The study discusses possibilities for more comprehensive and integrated CBDRM framework of vulnerable communities that can be implemented at grassroots level.

Submission ID: 117

Unraveling the Territory: A Systematic Review of Literature on Sensemaking in the Territorial Context

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Abstract

This study aims to analyze the state of the art of the concept of territory-based sensemaking, seeking to identify key elements, trends, and research gaps and investigating the interconnection between territory and sensemaking, uniting the two dimensions. As a specific objective, we seek to understand how sensemaking is formed in planned territories as a product of the real estate market. To this end, a systematic literature review was carried out in the Scopus database, covering the period from 2000 to 2023, which resulted in a corpus of 18 scientific articles. Data analysis took place using content analysis and statistical treatment tools such as Vosviewer to cross-check keywords and statistical treatment of abstracts using Iramutec software.

Based on the statistical results obtained by analyzing the article summaries using the Iramuteq software, five distinct classes of words were identified and grouped according to their semantic similarities and differences. These classes were named according to the sets of words suggested by the software: Organizational Studies, Urban Development, Collective and Governance, Place and Context, and Smart and Creative Communities. This approach allowed a deeper understanding of the conceptual and thematic diversity present in the articles analyzed, contributing to the understanding of the dynamics present in studies on sensemaking and territory. Preliminary analyses indicate that this discussion is possible and is multidisciplinary. Thus, it has the potential to shed light on the spatial, social formation and dynamics of planned territories, seeking to form a theoretical framework for the creation of sensemaking in planned territories as a product of the real estate market.

Through the evolution in the understanding of sensemaking training that is attributed to territories, more effective strategies and actions can be identified to promote sustainability in these regions, aligned with the UN Sustainable Development Goals (SDGs) for the year 2030. The study relates with greater proximity to objective 11, which seeks to make cities and human settlements inclusive, safe, resilient, and sustainable—connecting especially with target 11.3, which aims to increase inclusive and sustainable urbanization and capacities for the planning and management of participatory, integrated and sustainable human settlements, in all countries. The context of the conference “Linking Mountain and Ocean Futures: rescuing the 2030 SDGs for sustainable livelihoods” implies recognizing that solutions for sustainability are comprehensive and need to connect different realities. This study on the state of the art of the concept of sensemaking Territory-based offers an opportunity to examine how understanding territory as a physical and social environment can influence communities’ decisions and actions towards sustainability and livelihoods. By investigating the interconnection between territory and sensemaking, especially in planned territories resulting from the real estate market, we can identify how perceptions and interpretations of built spaces influence people’s practices and behaviors concerning the use of resources, the adoption of sustainable practices, and the development of a balanced livelihood.

Submission ID: 133

Bangalore's Lost Symphony: Learning from Traditional Water Management System for a Sustainable Urban Future

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Abstract

Dating back to ancient times, the relation between water and cities is unique. This relation weaves a distinct identity for each of these cities and its inherent populace, by means of their water harnessing techniques and their association with the adjacent water-bodies. This notion is also identified in SDG 6, which focuses on sustainable management of water and its availability to all, through the targets 6.5 and 6.6 aiming at *integrated water management solutions* and *protection and restoration of water related ecosystems.* The existing literature review reveals the need of sustainable water management practices of the indigenous local communities across the globe (Feyen, Shannon & Neville, 2008). At present, there is a lapse in the translation of the traditional wisdom of vernacular water management system of the past to the current practices and way of living. It is further researched that the natural water features, which used to be integral to the origin and evolution of urban landscapes, have been reduced to unwanted backyards in the present cities. Against this context, the present research aims to: (a) identify the key aspects of prevalent traditional water management system; (b) analyse its role as an integrated urban water management system and its impact on urban settlements. To meet the need of the aforesaid objectives, this research has selected the Bangalore region, which is known as the 'Region of Thousand Tanks'. The city of Bangalore is located on a ridge in the Deccan Plateau, where it is drained by three valleys, which feed into the tributaries of the river Cauvery. Since ages, this city sustains on a system of interlinking water-tanks, connected through a network of water-channels or storm-water drainage system. This network was constructed, following the topography of the city's location and terrain.

The insensitive planning approaches catering to the future urban development trends of Bangalore, have resulted in the ignorance of urban water-bodies among the stakeholders. The present work considers primary research as a key aspect to get a holistic idea of the context. Pilot survey, expert opinion survey through structured and semi-structured interviews were adopted for this research. This paper compares the historical water-management system with its current scenario, to analyse the impacts of compatible and non-compatible land-uses on the urban water-bodies, in the current context of Bangalore. The collated data reflects on sustainability as a way of living, practiced by indigenous communities, which advocates safeguarding the natural resources and symbiotic living of the local settlements. Further, analysis of the critical factors (affecting the sustenance of urban water-bodies), guides in arriving at solutions, which are inspired by indigenous past practices. This research contributes towards identification of (a) the transformation patterns of urban water-bodies and their surroundings and (b) the factors responsible for the degradation of Bangalore's historical water-management system. This comprehensive approach should aid in the detection and prevention of further damage to its present water network. This research would be useful for researchers, policymakers, urban planners and stakeholders at various levels, to enhance the quality of urban water-bodies.

Submission ID: 143

Application of GIS towards Disaster & Climate Resilient WASH Service Delivery in Nepal

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Abstract

The access to sustainable and reliable water sanitation (WASH) services has been affected by the impacts of climate change. According to the 2022 GLAAS report, approximately 40% of the countries have incorporated measures to address climate change risks to WASH services in their national WASH policies or plans. Nepal is one of the vulnerable countries to climate change, yet it is not adequately prepared for its impacts.

This paper explores the use of Geographical Information System (GIS) in enhancing the resilience of WASH services to disaster and climate change, specifically by building the capacity of the government officials and water sanitation users at the municipal level. It aims at understanding the local context and creating a critical WASH infrastructure map to contribute towards planning the resilient WASH system. The study includes a methodology that involve secondary literature review on GIS usage in climate induced disaster in urban area and primary data collection through consultation with the relevant municipal and national WASH portal officials.

The study found out that a critical WASH infrastructure map prepared with involvement of local water sanitation users and municipality officials provides a realistic ground information and updates. To develop a comprehensive critical WASH infrastructure map, geo-tagged location of water and sanitation infrastructures, along with potential hazard areas, is collected using 'Kobo toolbox'. Subsequently, this data is mapped using GIS and verified by local government officials and water sanitation users. With the aim to integrate these datasets in the national N-WASH portal, the data formats are aligned with the N-WASH database format. This data integration into the national portal will contribute to the development of knowledge & skills based on evidence, fostering political will and prioritization for climate resilient WASH service delivery. This aligns with the recommended prioritized activity outlined in the multi-stakeholder Climate Risk-Informed WASH Bottleneck Analysis of Nepal conducted in 2023.

Submission ID: 160

Towards Inclusive Urban Water Security: Capturing Community Perspectives on Water Risks in Emerging Cities to Enhance Resilience.

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Abstract

Urban water crisis is exacerbated due to global urbanization and climate change impacts. In response the evolving research paradigm for urban water security increasingly inculcates various associated water risks and a community-oriented scholarship to foster a more inclusive, resilient and sustainable urbanism. Hence, it becomes important to explore how community perceive their risks and which critical factors influence their resilience or vulnerability. The research was designed to empirically embed external and internal, biophysical and social factors of hydrometeorological risks, built-environment, socio-economic demographics, perceptions, attitudes participation and representation respectively in resilience framework. A case study of emerging city of Dehradun from India was selected where the research gathered social perspectives on the risks in a critical hotspot through a semi-structured questionnaire from 452 respondents at the neighbourhood-level, and subsequently analysed them in exploratory and explanatory multi-factor analysis to identify the key determinants for urban water security. A close synergy between the socio-economic demography and the built-environment was observed. The results indicate that household income, education, and size; dwelling unit plot size and structure were the critical internal socio-spatial determinants for urban water security. The results for perceptions about external biophysical factors indicate that though there is a general high agreement on periodic months of water insecurity, a differential impact duration among various community groups is observed due to different internal and external social and biophysical factors. This is certainly significantly more for groups with low education and poor income. Participation and representation were an important enabling factor for urban water resilience. The results show very little percentage of participation and representation in the study area, yet, the role of participatory process was a crucial external social factor in determining urban water security for those who had good interaction with their local leaders or government agency, and received help and support in times of need. Based on the results. Effective participation and representation can enhance water security but its absence can adversely impact the livelihood, health or property of different groups even within one community which can lead to inequity and injustice. Thus, the perception and attitudes towards external biophysical factors are influenced not only by internal biophysical and social factors but also by external social factors. Hence, in order to foster a 'just' and equitable resilient strategies it is important to consider the internal social and biophysical factors in conjunction with participatory processes that enable better inclusion while effectively capturing the perceptions as well as aspirations of the community.

Submission ID: 205

Resilience Governance of Shanghai's Tourism in the Post-COVID-19 Era

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Abstract

Resilience, as a pivotal concept in confronting environmental hazards and disasters, has experienced robust development in the past decade, emerging as a focal point of contemporary scholarly inquiry. Previous academic investigations, spanning from seismic events, floods, and hurricanes to strategies for disaster mitigation within socio-ecological systems and spatial planning, have progressively expanded to encompass diverse dimensions such as resilient urbanism, community resilience, and industrial resilience. However, since 2020, the onset of the COVID-19 pandemic, deemed the most significant global crisis since World War II, has posed formidable challenges and crises across political, economic, and societal domains. Preexisting resilience frameworks and risk society paradigms, formulated to address global climate change and environmental hazards, now confront a rigorous test in the face of the COVID-19 global pandemic.

Amidst these circumstances, world cities, deeply entrenched within the fabric of economic globalization, have notably borne the brunt of these impacts. Their international economic and trade engagements, cross-border flows of population and finance, and tourism sectors have experienced profound disruptions, with the tourism industry being particularly affected. This study focuses on Shanghai, representing one of these world cities, and investigates its tourism industry. Utilizing the TOPSIS model, the study constructs a resilience assessment framework for the tourism industry in the 'post-pandemic era', evaluating Shanghai's tourism sector's capacity for response, adaptation, and transformation since 2019 through the lens of Actor-Network Theory (ANT), thereby reconstituting the resilience triad of resistance, recovery, and transformation underpinning resilient tourism development.

Findings from this study reveal that Shanghai's diversified economic structure and rich tourism resource base have underpinned its capacity to withstand the impacts of the COVID-19 pandemic. Proactive revitalization policies and agile adjustments in local government tourism strategies have guided tourism stakeholders towards the development of diversified tourism products tailored to the unique features of COVID-19, fostering a secure domestic tourist market and endowing Shanghai's resilient tourism sector with adequate recovery resilience amidst 'zero-COVID' policies. In the post-pandemic era, the convergence of online and offline realms, coupled with policy interventions and stakeholder engagements, will drive the tourism sector towards a more diversified trajectory of transformative redevelopment.

6c. The Power of Art and Culture in Sustainable Cities and Communities

Abstracts

Submission ID: 61

Volunteering as a Synergy of Cultural and Social Capital in Building Local Identity

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Abstract

Human capital theories have evolved to a more comprehensive concept that encompasses health, skills, and competencies, which focus on people's attributes and identity as catalysts for social, cultural, and economic change. This can be observed in how small communities outside of large urban areas function. Contemporary rural or urban-rural communities are diverse, and the individuals who create the local community influence the development and well-being of the residents. These communities form informal or formal organizational structures that allow them to undertake various activities aimed at their own development, the acquisition of competencies, knowledge, or skills, and the field of action is frequently connected with the local heritage. Thus, we can observe a traditional approach using the history and traditions of the region and the creation of new heritage, which draws more or less from local tradition. In both cases, the activity is based on the voluntary and selfless commitment of individuals. The contemporary perception of volunteering is moving towards adaptation for achieving common goals homelands, creating a new perspective for building a belief in the attractiveness of a place among both residents and visitors. In this way, human capital creates social capital and contributes to sustainable development. The following topic was derived from research on volunteering, will be published in a scientific monograph, and for this text, we have extracted the proposed component that is related to the development of local activities based on the involvement of individual residents. This component is reflected in the present-day functioning of rural housewives' circles in Poland (KGWs) and local activity centers (CALs). KGWs are a specific form of activity that originated in the 19th century and continued to exist during the communist era. However, they were reduced to supplementing the offer of village events. Now, they are being revitalized. CALs, on the other hand, are a relatively new type of form, resulting from a systemic approach to activating local communities. To obtain a greater saturation of data and to make it more representative, we supplemented the earlier research by interviewing representatives of KGWs and CALs. The changes that are happening in local communities make it necessary to adopt a new approach to volunteering, one that emphasizes its role as a desirable form of civic activity, a tool for social integration, and a bonding dimension of voluntary activity. This type of volunteering is characterized by its care for tradition and historical continuity, local identity, and the symbolism of what is socially valued. The symbiosis in the approach to understanding socially important issues presents opportunities for cooperation, inclusive solutions, and practices that build resilience in global society using human and social capital.The UN Agenda 2030 identifies building social dialogue, social support, and trust between public actors and their partners as one of its primary objectives for the achievement of development goals. When viewed through the lens of human capital, volunteering can help convince stakeholders to create the right conditions for the formation of specific attitudes and behaviors needed to achieve objectives in line with the public interest.

Submission ID: 141

Cultural Sustainability and Cultural Ecosystems Related Aspirations and Emphases in European and Ibero-American Capital of Culture Programmes

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Abstract

The European and the Ibero-American Capital of Culture (ECoC and IACoC) programmes are the world's longest running Capital of Culture (CoC) initiatives. The ECoC was launched in 1985 with the Greek capital city Athens as the first title holder. Six years later, in 1991, Bogotá in Colombia was the first city to celebrate its IACoC year. Over the years, many changes and developments have occurred in both CoC programmes, not just regarding their organisational and funding models but also in their selection criteria, aspirations, and priorities concerning sustainability.

In the proposed presentation, which is based on the second article of PhD dissertation, how the cultural sustainability and cultural ecosystems related criteria and goals have developed over time in the official agendas of the ECoC and IACoC will be analyzed. In addition, how such developments are reflected in the programmes and emphases of designated Nordic and Latin American CoC cities in the 2000s will be studied. It is interesting how the two concepts are addressed and if and how they are seen as interlinked in the ECoC and IACoC agendas and programmes. Cultural sustainability, both the internal sustainability of the cultural sector as well as to the wider role of culture in advancing sustainability aims in other areas. Cultural sustainability as an ecosystemic question was studied, the cultural sector as an ecosystem, consisting of various relationships, networks, interconnections, interdependencies, and exchanges that take place and have an impact at different levels, e.g., within and between particular cultural ecosystems, with different societal areas and policy sectors, and between local, national, and international levels.

The article is still a work-in-progress, and the findings to be presented at the conference will be preliminary. The data consist of existing documents, including meeting agendas, legislative acts, declarations, and websites of the ECoC and IACoC, as well as official programme documents and reports of designated CoC cities. To analyse the data, I will use the frame analysis method to study how the concepts and understandings of cultural sustainability and cultural ecosystems are framed, i.e., how they are interpreted and constructed in the context of the CoC programmes.

The paper is closely related to sustainable development questions, approaching them in the context of culture and cultural policy. Although not directly linked to a specific SDG, several goals (3, 8, 9, 10, 11, 12, 13, 16, 17) are very relevant from the point of view of CoCs. The research is also relevant for the main theme of the conference: it specifically approaches cultural sustainability through an ecosystemic lens, highlighting connectivities at different levels as essential sustainability considerations. Moreover, I aim to actively and consciously challenge the Western- and anthropocentric perspectives that still prevail in the academic discussion on (cultural) sustainability and, I believe, limit our understanding of sustainability issues and potential solutions.

Submission ID: 148

The Affective Power of Art: The Meat Norm and Affective Communities in the Debate around Finnish Artistic Group Gustafsson & Haapoja's *Pigs* Exhibition in Seinäjoki, Finland.

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Abstract

In Finland and in many societies where meat is produced on an industrial scale, a change in the role of meat as a cultural food norm is needed for a sustainable, climate-resilient and more ethical food system. To maintain the meat norm, people attach their emotional status to eating and producing meat. Emotions bring certain subjects together - forming an affective community - and turn them against others.

In this paper, the unveiling of affective communities in the events and discourses around the Finnish artistic group Gustafsson&Haapoja's solo show Pigs (2021) was studied. Consisting of three conceptual installations, the exhibition discussed ecological and ethical questions concerning pork production and questioned the oppression of pigs as material. In 2021, the exhibition was on display in a municipal contemporary art gallery Kunsthalle Seinäjoki, Finland, conducted ethnographic fieldwork was conducted, and worked as a curator. Seinäjoki is a mid-size town in a meat-producing district in Western Finland. The exhibition generated extensive media coverage, and sparked heated debate through, for instance, provoking the neighbouring town of Kurikka to ban the exhibition from school adolescents.

Drawing from data that consist of the field journal and opinion writings published concerning the exhibition, to increase understanding of the affective communities connected to meat production and meat-eating. Further strive to find out how art can make us more aware of animals, make cracks in the meat norm, and pursue change through awareness. As one of the organizers of the exhibition, and therefore, an agent in the events, autoethnography as part of a wider ethnographic approach in the study was used. In the events associated with pigs, communities linked to the normative status of pork production can be seen as affective communities that, in responding to the exhibition, are reacting to signals and proposals for social change. The media frenzy caused by the exhibition is largely attached to the affective practices of defending the meat norm. The themes of death and killing arise as central notions. In addressing and tackling injustice in society the politics of mourning should be considered. When the authors in my data mourned for the farm pigs represented in the artworks, they considered the pigs as once living beings, not as material or as "meat" or "livestock". Questioning a norm can change the affective relationship with the norm when our emotional investment starts to change. My findings indicate that the connections to affective communities make the change more complex: we should be more aware of the animal in a more tangible way and that awareness can be pursued through experiencing art.

This abstract relates to the following SDGs and SDG targets: Sustainable cities and communities (Target 11.6), Responsible consumption and production (Target 12.8) and Climate Action (Target 13.3), and contributes to the conference theme by providing new insights into the power artistic expression can have on cultural change and how art can provoke societal discussion on urgent matters.

Submission ID: 213

Theatre-Based Initiatives for Urban Sustainability Transformation: A Literature Review

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Abstract

Global environmental and social challenges, such as climate change, biodiversity loss, natural resources use and social equity, urge the need to protect ecosystems and build inclusive societies. Cities and urban systems play a paramount role in such paradigm change as they are at the forefront of global transformation. Scholars in urban transformations and scholars in socio-ecological systems have shown the importance of agency and interaction of individuals for transformation as one of the critical components for fostering bottom-up approaches towards a sustainable urban. The concept of transformative space is emerging to develop the necessary agency and interaction. Transformative spaces are transdisciplinary solution-oriented collaborative environments enabling dialogue, reflection, and reflexive learning. There are many approaches for experimentation in these spaces, and arts-based research is developing in the field. Scholars have recently targeted theatre as a transformative engagement approach.

Performing theatre promotes creativity and resourceful solutions and consuming theatre improves empathy, changes attitudes, and promotes pro-social behavior. However, in transformative research, theatre (and broadly arts) is often used as a facilitation procedure where the researcher guides the participants through the process. Theatre (and arts) is seen as a more engaging technique, but there is always the researcher's intervention. There is little work on theatre (and drama) for triggering urban transformation imaginaries, with few interventions from a researcher. This study aims to address these gaps by exploring, expanding, and assessing the role of theatre as a transformative space for urban socio-ecological systems.

The research will do a literature review of theatre-based initiatives for urban transformations. This research seeks to contribute to our understanding of both bottom-up and top-down initiatives using theatre as a transformative space for urban socio-ecological systems. The findings will shed light on the efficacy of theatre in fostering urban transformation imaginaries, the dynamics of power within these performances, and the perceptions of spectators regarding the envisioned urban transformation futures. Overall, by focusing on theatre-based initiatives for urban sustainability transformation this research contributes to SDG 11.3 (enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management). Also, theatre as a practice connects people's livelihood and their culture, in line with the conference's theme.

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Submission ID: 220

Temporary and Mobile Art Initiatives: An Opportunity for Large-Scale Urban Development Projects and Beyond

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Abstract

Flemingsberg is suburban setting in southern Stockholm characterized by infrastructure elements as a major railroad to the capital passes right through, accompanied by roads and large-scale houses that accommodate a major hospital, district court and other public facilities as well as residents. The area is today fragmented, with roots in the so called 'million program' a housing project of the 60s and 70s, and is nowadays characterized by segregation, physical and social barriers, and with related socio-economic challenges.

In coming decades, central parts of Flemingsberg will become a construction site, as an emerging regional city centre takes shape in the 'midst of the fragmentation'. To cope with emerging challenges: the large-scale construction phase, and for pro-active preparations of the future, different types of initiatives will be undertaken. A mobile art initiative is one of them. This initiative is based on opinions expressed by current residents. According to them, the neighborhoods have been forgotten in terms of both maintenance and access to culture and services. There are also present concerns and criticisms regarding the development that will be carried out in Flemingsberg, as well as a desire of the community to be more involved in the planning of the new city center. It is furthermore related the municipality's responsibilities to support inhabitants' access to art and culture as well as to private real estate Company's interest in creating value. All in all, the study we are conducting suggests that art initiatives are both an important means of community participation in the development of urban space, as well as a possible way of (re-)generating the living idea of the commons. The purpose of our paper is to present and reflect upon concepts of permanence and mobility/temporality in art, in the designed living environment and to explore if and how art can contribute to resilience in large-scale urban development projects. Empirically, a municipal initiated project will be in focus, in which artists, residents and urban construction actors will be invited to participate. As a way of triangulating our reflections, we will include the voice of a London based multidisciplinary artist, Dominika Kieruzel, who has been working with similar challenges since more than a decade in the suburb of Thamesmead which can be said quite similar to Flemingsberg in several important regards.

In the project, there is a special interest in art and culture related to participation and co-creation as fundaments for a participatory and democratic society, the commons, and public benefit. We believe that such an approach to the commons may help in generating of a sense of safety and belonging in a suburban setting with socio economic and segregation challenges.

This paper relates to a number of SDGs. We relate to SDG 11 *Sustainable cities*. We furthermore lean on UNESCO's thematic indicators for culture in the 2030 Agenda; culture and participation (SDG 9,10,11,16), knowledge and skills (SDG 4, 8, 9, 12, 13), prosperity and livelihood (8, 10, 11), environment and resilience (2, 6, 9, 11, 12, 13, 14, 15, 16).

Submission ID: 229

Unveiling Cultural Gems: Exploring the Intangible Cultural Heritages of the Limbu Community for Developing Cultural Tourism in Darap, Sikkim

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Abstract

Sikkim is a north-eastern state in India. Sikkim offers mesmerizing views of the Himalayas and thus, this state is very famous among the tourists and nature lovers. Tourism is one of the most important contributors to the GDP of Sikkim. A large number of residents of Sikkim are thus involved in the tourism sector, either directly or indirectly. This state has a rich cultural heritage. Numerous ethnic communities are present in Sikkim. Among these communities, Nepali, Lepcha and Bhutia communities are predominant in this state. Every ethnic community of Sikkim is different from the other communities. Each ethnic community has different customs and traditions. Limbu is a tribe of Sikkim that belongs to the Nepali ethnic community. Limbu tribe has unique cultural practices, customs, traditions etc. This tribe has its own festivals, traditional music and dance forms, food, fairs, etc. that make this tribe unique in terms of culture and distinguish it from the other tribes and ethnic communities of Sikkim. Darap is a village in Gyalshing district (earlier West Sikkim district). It is only 8 km away from Pelling, a famous tourist destination. Darap is mostly occupied by the Limbu population. Tourism can be developed in Darap based on the exclusive cultural elements of the Limbu tribe. Tourism will also support the locals of Darap by providing job opportunities to them. Thus, tourism will eventually help the economy of Darap to flourish. This research work will try to understand the intangible cultural identities of the Limbu community of Darap and their potential appeal to tourists. This research work will be based on quantitative approach. The primary data has been collected through a predefined set of questionnaire and survey method has been used to collect the primary data for investigating the potential ways for using intangible cultural heritages of the Limbu community for developing sustainable cultural tourism practices in Darap.

Submission ID: 240

Studying the Cultural Landscape and Economy of Kathputli Colony's 'Street Performers' in Delhi

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Abstract

Delhi is home to many artists and laborers from other states, and as a metropolitan area, it offers numerous opportunities for outsiders to make a living. Delhi's Kathputli colony, which dates back to the 1950s, is well-known for its street performers, the majority of whom are from the state of Rajasthan. These street artists execute a variety of Rajasthani traditional folk arts for their livelihood. Especially recognized for its Kathputli art (puppeteers), but it is also the home of various musicians, dancers, acrobats, magicians, snake charmers and other folk artists.

Here, providing a comprehensive and in-depth explanation of the field is the goal. To go deeper into the issue or subject, a qualitative approach has been applied in the current study. The study examines their cultural landscape, where these street performers' economy is primarily focused on achieving specific objectives. The Delhi Development Authority initially demolished the illegal colony they had created in accordance with the Delhi Redevelopment Plan. The majority of them were relocated to temporary transit camps in Anand Parbat, where they are still residing in squalid and degraded conditions. They used to perform in most open, public locations, but those spaces are now mostly unavailable, therefore their economy has faced several challenges and changed with time. A number of art forms performed by these street performers have vanished, while a few others are progressively disappearing and becoming less prevalent. The study's overall focus is on the cultural landscape and cultural economy of street performers, which have changed significantly over the course of their existence. Many artisans have already left Delhi as a result of the difficulties and issues they encountered, and those who have managed to stay are working hard to make ends meet as they wait for the commitments given by the Government of Delhi. This paper will also address the sustainable approaches to the rehabilitation and relocation of these artists, as well as the revival of traditional folk forms of art.

Keywords: *Street Performers, Cultural Landscapes, Folk Art, Cultural Economy, Sustainable Approach*

Submission ID: 266

The Design Practice Exploration of Work Well-Being in Sustainable Development Theory in Urban Public Art: A Case Study of 2023 Changsha Public Art Plan "Are We Becoming Labour Machines" Design Project

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Abstract

Public art is an important part of urban art and culture, which directly affects the thinking and behavior of local residents. With the sustainable design concept elicited by sustainable development theory, public art can inspire people's resonance through speculative interactive installation, so as to pay more attention to sustainable development. Through reflection on design, a more sustainable society can be created. The well-being of work, such as the protection of labor rights and the right concept of work, is an important part of the concept of sustainable development, which affects human well-being and the future.

Changsha Public Art Project "GaZang" is a public art project supported by the local government and organized by UCCA to awaken the vitality of the city and the sense of identity of residents. As part of this, my project "Are We Becoming Labour Machines" responds to the SDG with the sustainable design theory, designing a public art interactive installation with the theme of well-being at work, inviting the audience to complete ridiculously repetitive tasks, rolling with repetitive music generated by repetitive work, and testing whether people are working machines, so as to arouse people's reflection on the current work ethics.

This paper will be carried out from the following parts:

1. Exploration of the relationship between sustainable development concept and public art;
2. The significance of work well-being as sustainable development concept in public art;
3. Work well-being in public art application case introduction which contains work well-being research, design development, design, audience response and feedback, reflection and discussion.

The project responds to SDG+Target 8.8

Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.

As stated in the introduction to the Conference, "sustainability is a way of living" that is not only environmental, but also social and cultural. The research and practice are related to the theme of the conference as follows:

1. Public art, as a medium, can effectively spread ideas and arouse thinking, and it provides a possibility to publicize the Sustainable Development Goal.
2. Well-being at work is an important part of the concept of sustainable development, and the research in this paper reminds people to pay attention to well-being at work and achieve a happier life.
3. Through sustainable living concepts and ways to make people concerned about the environment, society and culture.

Full Papers

Submission ID: 60

Audience Development Management in the Context of Sustainability in Cultural Institutions

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Abstract

The contemporary discussion on the role and place of the audience in the achieving SDG means the active role of the audience in the creation of culture is recognised; they have become both a co-creator and consumer of the values created and the most important stakeholder of cultural institutions. Institutions pursue their objectives in various ways, including artistic activities (investing in the development of human capital, which builds social capital), and managing their relationship with the audience (e.g., through marketing or educational activities). In their assumption, they are supposed to lead to maintaining a kind of balance and equilibrium in the functioning of a cultural institution in its social environment. In the conducted research, it was decided to verify this approach and take a closer look at the practices that are important for achieving the strategic goals of cultural institutions, including maintaining a dialogue with the audience and building relations. The results of the statistical analyses and qualitative research indicated a gap between the awareness of the importance of the audience and efforts aimed to effectively achieve their own strategic goals and public policy objectives. It results, among other things, in an underestimation of the audience's influence on the functioning of cultural institutions, a lack of competence (especially in the use of management tools and techniques), or a lack of awareness of the responsibility of cultural institutions towards society.

Introduction

The importance of the audience as an active partner in cultural dialogue is becoming increasingly important in the context of the challenges of the modern world. As recently as the 1990s, audiences were mainly understood as recipients of culture, assumed to be passive, who at most "voted with their feet", taking advantage of a given offer or not. The main attention of cultural institutions was directed towards marketing, which used increasingly sophisticated tools and techniques to attract audiences. The contemporary discussion on the role and place of the audience in the strategic management of a cultural institution is the result of discussions and successive international agreements related to the achievement of the Sustainable Development Goals since the 1970s. These goals, currently formulated as the 17 Sustainable Development Goals (United Nations, 2015), have determined public policies in many countries and have been enshrined in strategic documents at the European Union, state and local levels, but also at the level of cultural institution strategies. Here, the active role of the audience in the creation of culture is recognised; it has become both a co-creator and consumer of the values created and the most important stakeholder of cultural institutions (Kolb, 2013). Audiences are put at the centre - they give meaning to the activities of cultural institutions by participating in events and expressing their opinions in direct interaction with the institution (McCarthy & Jinnett, 2001), and audience development has become a strategic goal.

Literature Review

The Audience as Key Stakeholders

In organisational management processes, several participants can be identified. Each of them has its own goals to achieve, making the organisation's goals the resultant of those of the participants (Cyfert, Krzakiewicz 2009). The concept of 'stakeholders' generally refers to business activities. However, it is reasonable to consider stakeholders in the context of public institutions (including cultural institutions), whose strategic objective is to focus on stakeholder expectations and whose goal is to create public value (Austen, Czakon, 2012). In Freeman's theory, stakeholders are individuals, groups (formal and informal) and institutions that interact with an organisation, can influence it and are themselves affected by it (Freeman 1984). Criteria for distinguishing stakeholders include, for example, identifying their relationship to the organisation's activities and assuming that there is a relationship between the organisation and its stakeholders that relates to mutual expectations (Austen, Czakon, 2012) or even the exertion of pressure (Obłój, 2014). By identifying stakeholders, it is possible to determine the role they play (or can play), in achieving the organisation's strategic objectives. Stakeholders are divided into:

1. Internal, i.e., directly related to the organisation, such as employees, shareholders, and management (supervisory boards, etc.).
2. External, i.e., those operating in the organisation's environment, such as customers, suppliers, competitors, government authorities, media, NGOs, etc.

The above classification may not be sufficient to divide stakeholder groups, so it is considered important not only to define who the stakeholders are but also what they expect and how they intend to get it (Frooman, 1999). Thus, for example, employees expect a safe workplace, fair remuneration, training, identification of development prospects (Aguilera *et al.*, 2007); customers: fair price, highquality product or service, after-sales service (Kotler & Keller, 2016); suppliers: timely payments, fairness in negotiations (Chopra & Meindl, 2016); investors: return on investment, financial transparency, long-term growth visions (Ross *et al.*, 2017); community: social responsibility (Porter & Kramer, 2011). Managing stakeholder relationships is an ongoing process that requires communication, engagement and responses to changing needs. However, it brings benefits to both the organisation and the stakeholders, such as a better understanding of the market and the environment (Harrison & Wicks, 2013), increased trust and reputation (Donaldson & Preston, 1995), achieving sustainability goals or increased competitiveness (Porter & Kramer, 2006).

Like customers in business, audiences play a key role in the activities of cultural institutions. "An audience is a form of collective life consisting of the separation of a certain group of people expecting similar experiences or interested in the same object or phenomenon”

(https://encyklopedia.pwn.pl/haslo/publicznosc;3964324.html). It is an active participant in cultural life, a group that consumes, interprets or reacts to some kind of news, performance or other form of expression (Abercrombie & Longhurst, 1998), and interacts with artistic content (Kolb, 2005). Audiences can be classified in a variety of ways, such as according to involvement: passive versus active (Livingstone, 1998), scale: mass versus niche (Webster & Phalen, 1997), relationship with the organisation: formal or informal (Heinich, 1999). As cultural institutions became more audienceoriented and open to interaction

(2nd half of the 20th and especially the beginning of the 21st century), the perception of the audience as passive participants began to change (Kotler & Scheff, 1997). Its importance is not only limited to the role of receiver of the activities of cultural institutions, but the contemporary audience is also more active, demanding and engaged (Simon, 2010). She is understood as a co-creator of cultural value (Simon, 2010), thus having a significant impact on the success or failure of the activities undertaken by cultural institutions, contributing to the achievement of strategic goals. Its opinions, comments and expectations are a valuable source of information for cultural institutions (McCarthy *et al.*, 2004), allowing cultural offerings to be better adapted to public needs and expectations.

The influence of the audience on the activities of cultural institutions can be analysed from different perspectives, among which we can mention: a) expressing opinions that can influence the direction of the institution (McCarthy *et al.*, 2004); b) communicating needs, expectations and potential areas of development for the cultural institution (Kerrigan, Fraser & Özbilgin, 2004); c) financial support - understood as donations, ticket purchases; d) promotion, in the sense of an active audience that can act as ambassadors for the institution, recommending events and spreading information (Kotler & Scheff, 1997). Recognising the audience as a stakeholder in the context of culture can lead to more inclusive, responsible and effective management practices. This approach makes it possible to create deeper relationships with audiences and better adapt to their needs. Understanding the audience as a central value in the management of a cultural institution is key to its success in a dynamically changing environment.

Audience Development about Achieving the Strategic Objectives of Cultural Institutions

The recognition of the audience as a key stakeholder carries implications for strategic management in cultural institutions (Thompson, 2007). Management is an ongoing process that requires communication, engagement and response to changing needs (Clarkson, 1995). Strengthening the relationship with the audience can be achieved here, e.g., through the implementation of a Customer Relationship Management (CRM) strategy (Payne & Frow, 2005), where the integration of business processes, technology and all activities of the organisation move towards a better understanding and satisfaction of customer needs (Kotler & Armstrong, 2010) This is achieved, among others, through market segmentation (Peppers & Rogers, 1997), personalisation (Sheth & Parvatiyar, 2001) or multichannel communication (Kumar & Reinartz, 2012).

Customer relationship management (CRM) is commonly used in business. However, in the context of culture, the term 'audience' seems more appropriate than 'customer', and the approach to relationship management needs to be tailored to the specifics of the sector (Kotler & Scheff, 1997). The fact that cultural institutions play a key role in shaping identities, promoting values and developing communities is also relevant here. Their functions have been and continue to be diverse, and adapted to the dynamics of socio-cultural change or public policy goals (Bennett, 1995). They are multidimensional and are constantly evolving in response to the changing needs of society, making it necessary for institutions to adapt to new challenges and trends while upholding their fundamental values. Thus, cultural institutions not only meet the needs of audiences but also influence their development. Among the most important functions of cultural institutions are such as:

- Educational. This is one of the main tasks of cultural institutions, which is crucial for shaping historical and cultural awareness (Kreps, 2003), promoting social and civic values (Hein, 1998), and developing critical thinking and empathy (Simon, 2010). In the twentieth century, the educational function of cultural institutions has evolved from traditional forms of teaching to interactive and participatory methods that support audience development (Simon, 2010). In doing so, it has taken advantage of developments in technology that have enabled remote learning and online access to cultural resources (Parry, 2010) and has placed a greater emphasis on inclusivity and accessibility for different social groups (Sandell, 2002).
- Identity. Cultural institutions play a key role in the formation of identity, understood as a sense of unity, belonging or defining characteristics of an individual or group (Hall, 1996). By displaying culture, arts and traditions, they reflect the values, beliefs and aspirations of a given society (Kreps, 2003) and help communities to understand their heritage. In this way, they contribute to and perpetuate a sense of national or local identity (Smith, 2006).
- Social. The social function of cultural institutions is a key element of their value to society. They often act as public meeting places where people can exchange thoughts, participate in discussions and engage in dialogue about relevant social issues (Simon, 2010). They contribute to social inclusion by offering a space for people to express themselves and share their stories (Sandell, 2002). They carry out activities to increase civic awareness, promoting values such as tolerance, respect and cooperation (Hein, 2000). They contribute to social well-being by promoting mental health, self-awareness and personal development (Silverman, 2010).
- Economic. Cultural institutions play a key role in generating income, creating jobs and attracting tourists (Throsby, 2001). Through ticket sales, events, membership programmes and other commercial activities, cultural institutions contribute to the local economy (Scott, 2006). The activities of cultural institutions and heritage management are also key factors in attracting tourists (Richards, 2011). Additionally, it should be noted that the cultural sector employs millions of people worldwide in both creative and administrative positions (Seaman, 2006).
- Innovative. Cultural institutions not only preserve and present cultural heritage, but also become places for innovation, experimentation and exploration of new forms of expression and communication (Holden, 2007). They are places where artists, curators and audiences collaborate to create new art forms and interpret traditional forms in modern ways (Landry, 2000). They use new technologies to do this (Parry, 2007; Belfiore, 2002) and promote creativity, critical thinking and problem-solving skills, preparing people for a world full of unpredictability and volatility (Simon, 2010).

Audience development refers to the strategies and activities undertaken by cultural institutions to increase the number, diversity and involvement of their audiences (Kolb, 2005), and is key to achieving the strategic goals of institutions in a dynamically changing environment (Kotler & Scheff, 1997). The concept of *audience development* developed mainly in Anglo-Saxon countries in the 1960s, where cultural events provided audiences with, among other things, educational materials, and meetings with discussions on topics related to the issues at hand (Morison, Dalgleish, 1993). The UK's New Audiences Fund programme (Johnson, Pfrommer, Stewart *et al.,* 2004), launched in the 1990s and continued thereafter, referred to the earlier concept and developed it in the context of the need to achieve goals such as increasing cultural participation - thus, the management of audience development in a cultural

institution became more closely linked to marketing (Plebańczyk, 2017). Nowadays, a move towards a combination of both approaches can be observed, with the strategies of cultural institutions following what the European Commission called audience development 'a strategic, dynamic and interactive process of art dissemination. It aims to engage individuals and communities in experiencing, enjoying, participating in and appreciating the arts through the various means already available to cultural operators" (European Commission 2012, p. 1).

Methodology

The presented results of the literature studies clearly show that audiences are considered the greatest value of cultural institutions. Cultural institutions declaratively place audiences at the centre of interest and their development as a strategic goal. In the research carried out, it was decided to verify this approach and take a closer look at management practices. For this text, excerpts from the research (fully discussed in the academic monograph) were used, focusing attention on the research questions, written as follows:

- What relationships are formed between the organisation and the audience?
- What is the management practice of the cultural institution in the context of audience development?
- What are the key challenges for managing audience development in cultural institutions? Research techniques were used to answer the questions, such as:

Secondary qualitative statistical data analysis. The research was carried out between 2021 and 2022, using electronic media and among audience-focused communities (groups were selected using keywords and non-random sampling, involving the recommendation of further groups by people working in the cultural field). From the 105 (raw and previously archived) survey responses, thematic issues were extracted (based on pre-programmed keywords), which served as the basis for the in-depth interviews;

Qualitative analysis of interview data. The research was carried out between 2021 and 2023, in the form of individual and group semi-structured interviews with 60 people representing cultural institutions. A non-random sampling (snowballing) method was also used to select interviewees by recruiting participants from other participants. Their statements were coded and then analysed using keywords, and expanded to include accompanying issues.

It should be noted that cultural circles are very reluctant to participate in research, and conducting surveys or interviews here encounters considerable difficulties. The results achieved, presented later in the text, are therefore limited in their focus, although they show the potential to extend the themes undertaken in the future.

Results and Discussion

Relationship between the Public and the Cultural Institution

The importance of audiences for the functioning of cultural institutions was emphasised by both survey respondents and interviewees in the in-depth research. Respondents, in their answers to the question about the importance of particular stakeholder groups, ranked the audience first (63.1% considered it the most important, 24.3% considered it very important and 9.7% considered it quite important), This is not

the only group whose importance was so strongly articulated, as it can be followed by employees (19.2% considered them the most important group and 51.9% very important). Among the other groups considered most important, the media and state authorities were mentioned next (considered most important by 12.9% of respondents), indicating a high awareness of the dependence of cultural institutions on public opinion and public policy directions. Other stakeholders such as shareholders, supervisory boards, financial institutions, suppliers, competitors and trade unions were ranked further down in the opinion of respondents.

The most frequently repeated slogan about the functioning of cultural institutions is the statement that 'without an audience, there is no culture'. It was also repeatedly mentioned during the interviews. One interviewee, in addition to stating this phrase, additionally emphasised: "I have always assumed that an event or cultural activity is when there is at least one audience" (JP).

The indication of the importance of audiences provides an important argument for discussing how cultural institutions interpret this importance. The respondents' answers show the main areas of the cultural institutions' activities in which audience issues come to the fore. Among these, the following can be distinguished:

- Increasing participation - 48% of respondents identified this as the most important area.
- Building relationships with the audience - for 41.3% of respondents this is a key area.
- Improving communication with audiences - 31.3% of respondents identified it as the most important.

Practically all areas of the cultural institution's activities are important but in the opinion of the respondents, they are of different ranks. Next in the hierarchy of importance, after those listed above, are: achieving the desired image, building an effective team, developing a programme of activities, developing working methods and tools, and co-developing grant applications. The statistical results are complemented by statements from the interviews, giving them interpretation. One person highlighted the closeness of the relationship between cultural institutions and their audiences, saying:

"I'll honestly admit that I hadn't fully realised how close cultural institutions are to the public. In the case of institutions such as houses, and cultural centres, the contact is very close and direct. It is a bit more difficult with other institutions that are more artistic and work on a different basis." (KP)

It is worth noting her recollections of her relationship with the public before the pandemic. IO said: "For as long as I can remember with our audience we always talked. [...] But it all happened before lockdown." (IO) These nostalgic memories underline how important it is for the institution to have direct contacts and conversations with its audiences, which was much more difficult in the era of pandemic restrictions. In the context of talking about relationships, SD noted that the criteria for the importance of audiences vary depending on the nature of the institution, emphasising: "It seems to us that only local issues and belonging to a local community can build a dedicated audience around an institution." (SD)

Selected Elements of the Management Practice of a Cultural Institution in the Context of Audience Development

Managing audience development is, according to the interviewees, an inevitable part of the evolution of any cultural institution. The essence of this development was perfectly summarised by one interviewee,

who stated that: "the whole story with audience development starts with presence" (ASz), understood as any kind of contact with already existing and potential audiences. MK put it as follows: "What we have here is the simple truth that to build a strong relationship with audiences, we need to be present to them" (MK). Its simplest terms means being able to adapt to the needs of the audience. As KS says: "We engage our audience in a specific way. Later, we check whether our solutions have caught on" (KS). Engaging audiences, listening to their needs and adapting the offer is key to building lasting relationships. As KZ points out, for many institutions this adaptation is not just a matter of choice, but a necessity: "For some institutions, the need to adapt becomes an impetus to engage in dialogue with the public. [...] Some undertake such activities consciously from the outset, others only learn to do so in the process" (KZ) Understanding the need for dialogue with the audience is fundamental to development and success.

(Dis) cognition of the public

Institutions face the difficult task of adapting to dynamic changing audiences. There seems to be a need for a more personalised approach to the audience, as AS recognised when he said: "In these community centres of ours, GOKs, MOKs and other places, we are constantly making discoveries" (AS). There were also comments about the fact that everything presented by cultural institutions comes at a price. MS said: "Everything we present carries a certain amount of risk. Every curator takes a risk when deciding on a theme or an artist. From the audience's point of view, evaluation is difficult, so they take different stances" (MS). Despite this, as SL points out: "Audiences may be unsure of their choice, but they still love live performances" (SL).

The key to recognising the audience according to interviewees is communication. One person said: "We try to talk to people, especially young people, parents and children, asking them about their experiences at different museums" (KM). Through this, one learns that while 'the audience needs to experience something, we don't offer a place where everything shines and you can push buttons to elicit a reaction. With us, action has a different level" (KK). The notion of experience came up repeatedly in the interviewees' statements. Another person put it this way: "It is about the experience we offer our audiences - from the moment they enter the institution until the moment they leave it" (OW).

(Dis) cognition is facilitated by research, as pointed out by ASz: 'Together with the research collective, we researched theatre audiences (...). An interesting conclusion came out of it, that most of its audience comes from outside of Warsaw" (ASz), or, as other research cited, that "young people from generation Z seem to be absent from many cultural institutions, which is a challenge to solve the institution's programming and marketing activities" (OS). According to ASz, "we can learn interesting things through research" (ASz), e.g., that "many people have a fondness for certain places but don't go there anymore" (ASz), or that institutions "point to the lack of Generation Z audiences as a problem" (MO).

It is worth bearing in mind that 'institutions rarely know how to conduct audience research, and even if they do, they do not know what to do next with the results' (KP). Independently, as if to confirm this, MK said: "We have not created a typical audience breakdown table. But we have two tools to identify it. One is a simple survey on the tables in the museum, consisting of two questions that we analyse regularly" (MK). Collaboration between institutions and a concrete example was given as an interesting example of addressing the lack of research competence. KZ said in this context: "Museums in Warsaw carry out joint

audience research, which is not funded by the authority. They work together to better identify their audiences" (KZ). In opposition to the expressed need to carry out audience research, there were also statements denying the need to do so. SL said: "In the philharmonic, it is enough to publish the repertoire and the performers to attract audiences. However, at present the audience is uncertain, they don't know if they want to come or are afraid" (SL).

The audience's experience with the cultural institution

The analysis of the relationship between a cultural institution and its audience leads to the issue of the totality of impressions experienced by the audience when using the services of a cultural institution. On the one hand, we are dealing with the diversity of audiences, on the other hand, with actions taken in response to their simplest needs (user experience). KP communicated this as the conclusions of the research: "I remember that the most important finding of this research was not what the audience's attitude to the theatre was, but the fact that queues form for the toilets during the breaks" (KP).The statement underlines the importance of listening to the audience and responding to their needs, even if they concern a seemingly trivial issue, something that institutions are increasingly paying attention to. In the context of technical service issues, MK-L highlighted: "The audience attendants are the group of people responsible for tickets and the cloakroom. We can describe them as the ticketing and cloakroom crew. Daily they take care of cloakroom matters, ticket control and directing the audience to their seats in the hall" (MK-L).

It's also a reminder that it's not just the artistic side that's important, but also the quality of the service that can influence the visitor experience. Analyses of the audience experience lead to broader measures that aim to provide for the basic needs of the audience in such a way that they can focus on the experience of participating in the offer. One interviewee pointed out that this is not a common practice in cultural institutions, citing as an example the situation after a screening in cinemas when "the lights are already dimmed and the staff in jackets are pointing as if to say 'Go now, the screening is over'"(AS).

The Customer Journey Map was regarded as a helpful tool by some of the interviewees who declared that they were involved in audience relationship management at the level of strategy implementation planning. In their opinions, it allows to look at the service of the audience from the perspective of the addressee of the activities, improves the sales process and the identification of the strengths and weaknesses of the sales path, and helps to provide the audience with a consistent experience at each point of contact with the institution. As highlighted: "I tell staff that sometimes I like to walk down the audience path after a few hours at the computer and that it's worth it" (AS).

Another more commonly used tool is - popular in CRM and marketing - audience segmentation. KZ, noting the diversity of audiences, said: "Our audiences, and more specifically our visitors, vary considerably. This is reflected in the ticket structure. When I look through the list and analyse the types of tickets, the discounts given and their distribution, I see this diversity" (KZ). JSz described it as follows: "Based on incomplete data, we distinguished segments: families, tours, tourists, pensioners, wealthier tours mainly from abroad, school trips, families with children and business tourists. We also singled out people from Krakow and beyond, creating a special offer for them" (JSz). In the case of another institution: 'We have defined our audience, which is divided into several groups. The key thing for us is that it is an audience

with a positive attitude towards contemporary art" (MS). OZ addressed the topic being addressed by saying: "We did a study on online audiences once. It's extremely challenging because online is a completely different audience, a completely different audience, a completely different content. This all happened before lockdown and we certainly have the desire and the urge a huge amount to face it again, it is a very big challenge because it requires a very big preparation, tools, effort and money" (OW).

The statements quoted show not only that cultural institutions are looking at their audiences, trying to be flexible and adapting their offers to the diverse needs of their audiences, but also what problems they face in doing so.

Challenges for Audience Development Management

Despite the unambiguous importance of audiences for cultural institutions and the expression of great interest in them, audience development management is often overshadowed by other activities. In the quantitative survey, respondents mostly indicated that there are no programmes or projects related to audience relations management in their institutions (67% of responses). As one interviewee noted: "We have this reflection that audience development management is something that is just in its infancy and many of our staff are just discovering how important this audience is" (OS). Survey respondents gave their understanding of the concept, and their intuitive definitions appear to be thoughtful and, at least in part, overlapping with the full definition of the approach in question. However, not all cultural institution staff are aware of what is meant by the term 'audience development'. As KM admitted during the interview: "Up to this point we completely had no idea about it, absolutely" (KM). Despite this, there is an awareness that audience development activities are 'very relevant' and important for the institution (MS).

Responding to audience challenges, the person in charge of the education department at one museum admitted: "I noticed a need, I noticed that building an audience was some kind of a gap with us. There was no one to take care of it, so I decided on my own that it was high time to start building this audience "(MA). This conscious effort to develop relationships with audiences seems to be the key to success. Although KP pointed out some inaccuracies in the language used by the institutions: "My experience is that in many cases institutions are doing things to develop audiences without necessarily using the language of governance to do so" (KP).

Managing audience development is a strategic objective for cultural institutions, BD-S pointed out an important aspect of the mission here, saying: "*Audience development* is an approach, I like to call it that, an approach that creates a kind of umbrella for the activities undertaken, an umbrella understood as a mission" (BD-S). Continuing this theme, he also stressed the importance of an individual approach to each audience, saying: "A public cultural institution can't afford big campaigns, so a fantastic solution here is *audience development*, in the form that aims to take care of every single viewer, to make them love what we do. The rest is taken care of by the viewer talking about it and sharing their experience with others. It is so trivial and simple " (BD-S). At the same time, he noted: "I know of very few institutions that have an audience development strategy, identifying this as a core element of their operation. Most institutions include it as one element of their strategy. Unfortunately, it is very often focused on marketing and communication issues, as well as serving the audience or music lovers. For directors, the biggest challenge is to accept that they should focus on the quality of the relationship with the audience" (BD-S).

The critical approach expressed in the above opinions does not contradict the fact that many cultural institutions aim to create a qualitative relationship with their audiences, involving people in the creative process, and offering interesting meetings or exhibitions. As JS confessed: "We would like more to play an active role in shaping social attitudes. We want to organise meetings with interesting people, organise cool exhibitions so that people who visit here can see us as a reference point" (JS). KZ notes that the key to success is a collaboration between different cultural institutions, rather than competition, saying: "In any case, what comes out of all this most importantly is that people have started to work together, not to be in competition with each other, but to start having a kind of dialogue with each other." He then added: "It is known that this competitiveness will be there because, in the end, everyone is fighting for the same customer, but this should not prevent us from having a dialogue, i.e. some things we can share, some things we can do together" (KZ).

While the challenges are manifold, organisations should strive for a deep understanding of their audiences, identifying their needs and adapting their activities to them. At the same time, as highlighted earlier, the key is to give space to the audience and allow them to actively participate in the creative process. A lack of patience was identified as one of the obstacles. As one interviewee put it:
"Institutions want quick and easy successes, they want crowds to come to their exhibitions and tickets to be sold out. But where the crowds do come, the programme is often very accessible and popular. As part of our audience development strategy, we want to develop competence and taste, to encourage people to do something more challenging. Because we know that this helps develop people and builds social competence" (BD-S). In the management of audience development, interviewees also found it important to link it to the strategic management of the institution, describing it as 'extremely formative for the institution, for our place in the city and the creation of new audiences' (MS), while emphasising how big a responsibility it is (MS).

Conclusion

Cultural institutions are deeply rooted in the communities in which they operate. Their success and sustainability largely depend on the relationships they build with their audiences. Analysis of the results of the research carried out allows them to be related to the research questions posed:

The relationship between the audience and the cultural institution**.** The audience considered the key stakeholder and the greatest value of the institution, is at the same time the ultimate goal of its activities, which is confirmed by the slogan: 'Without an audience, there is no culture'. The results of the research indicated that:

Different areas related to the audience. Cultural institutions emphasise interaction with audiences in various areas of activity. The most important issues for respondents were increasing participation, building relationships and improving communication with audiences.

Diversity of cultural institutions. The relationship with the public varies according to the nature of the institution. For institutions such as community centres or cultural centres, the relationship was more direct and close, while other, more artistic institutions, may operate differently. This highlights that there

is no uniform approach to audience management. It is also important to recognise the need for a more personalised approach to audiences in the context of a dynamically changing audience.

The importance of direct contact. The pandemic and the restrictions put in place have strongly affected the relationship between cultural institutions and their audiences. Direct contact and conversations with audiences are extremely valuable and their absence was highlighted during the lockdown.

Cultural institution management practices in the context of audience development. Managing audience development is an integral part of the implementation of a cultural institution's strategy. Against this background, the relevance of the issues presented below was highlighted as a result of the research:

The importance of presence and relationship building. Audience development starts with presence, which means keeping in touch with existing and potential audiences.

Adapting to the needs of the audience. Cultural institutions should engage their audiences, listen to their needs and adapt their offerings to them. This process is essential to building lasting relationships.

Individualising the approach. There is a need for a more personalised approach to the audience in the context of a dynamically changing audience.

Risk and uncertainty. Every action of a cultural institution carries a certain amount of risk, and audiences are often uncertain in their choices. Managing audience development should neutralise these.

The effectiveness of audience development management. Although cultural institutions recognise the need to develop relationships with their audiences, many struggles to fully understand the concept and lack competence in the practical use of a variety of methods and tools. The solution to the problem may lie in cooperation between institutions.

Challenges for audience development management. Key findings from the research include:

Managing audience development is key to achieving the strategic objectives of cultural institutions. Despite awareness of the importance of audiences, activities in this area are often overlooked or underestimated by cultural institutions.

Lack of concretised programmes. The survey found that 67% of respondents indicated a lack of audience relations management activities in their institutions.

There is a need for education on audience development management. Many employees are not aware of what exactly 'audience development' is, although they intuitively understand its importance.

An individual approach to the audience is the key to success. The need to build individual relationships with audiences, rather than focusing solely on marketing issues, is essential to the success of a cultural institution.

The need for cooperation between institutions. The key to success is cooperation between different cultural institutions, not competition. Cooperation benefits both the institutions and their audiences.

Understanding and adapting to audience needs. Institutions should thoroughly understand their audience and use participatory tools to increase their engagement.

Combining audience development management with the strategic management of the institution. This synergy is crucial to the institution's position in terms of its place in the community and to the creation and development of new audiences.

Accountability of institutions. Managing audience development involves a high degree of accountability on the part of institutions to their audience and the community of which they are a part.

At the same time, the conclusions presented should be considered as elements for further discussion. Each of them can be developed in the context of other studies focusing on the issues discussed.

Cultural institutions are set up to perform specific functions and face many challenges. Despite the recognition of the audience as a key stakeholder, in practice, the approach to managing audience development can only be declarative. The central role of audiences means that institutions are forced to have a deep understanding of audiences and to see them as co-creators of cultural activities, which poses challenges in terms of effective management and relationship building. There is therefore a need to build informed and engaged audiences while avoiding the pitfalls of commercial approaches and focusing on authentic relationships with audiences. In light of these reflections, it seems that collaboration, dialogue and active audience participation in the creative process are crucial.

It is a dialogue that plays a key role here, enabling cultural institutions to effectively communicate and interact between two parties. This is because it presupposes mutual understanding and exchange (Buber, 1970), and influences relationship-building and audience engagement (Kent & Taylor, 2002). Dialogue reflects a democratic approach to culture in which audiences become active participants and not just passive observers (Bickford, 1996). Cultural institutions that engage in dialogue gain a deeper understanding of the needs and expectations of their audiences, which in turn enables them to create more personalised and engaging experiences (Grunig, 2009). Dialogue allows an organisation to better understand its audience. This enables strategies, products or services to be tailored to the real needs of customers or stakeholders, while also supporting the building of lasting trust and loyalty.

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The Preservation and Evolution of Cultural Assets in Tamsui: Shaping the Vision of Sustainable Development through Art and Literature

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Abstract

This study analyses the preservation and evolution of Tamsui's cultural assets in Taiwan from 1972 to the present, exploring how literature, art, and reportage have shaped the vision for Tamsui's sustainable development. The focus is on several key cases: the campaign to reclaim Fort San Domingo, the expansion and preservation movement of Tamsui Old Street, the campaign to save Tamsui Little White House, the Tamsui River North Expressway movement and Tamsui River Rescue Alliance, and the preservation movements for the Sixth Road of the Tamsui Urban Plan and Chongjian Street. The findings reveal that the preservation and evolution of Tamsui's cultural assets involve a complex interplay of various stakeholders. Through attention and discourse on cultural heritage, it is possible to address the challenges of preservation and development under the pressures of environmental development and tourism. For Tamsui to achieve sustainable development, it is essential to form narratives within the system, while also maintaining external forces. Literature, art, and reportage play crucial roles in shaping a vision of sustainable development, allowing new relationships to emerge between history and reality.

Introduction

Tamsui is an ancient town in Taiwan with a rich historical and cultural landscape and architecture. However, since the 1970s, the pressures of environmental development and tourism have led to the destruction of many valuable streetscapes, riverside environments, and historical buildings. Significant cultural heritage preservation events in Tamsui include the campaign to reclaim Fort San Domingo, the movements for the expansion and preservation of Tamsui Old Street, the campaign to save Tamsui Little White House, the Tamsui River North Expressway movement and Tamsui River Rescue Alliance, and the preservation movements for the Sixth Road of the Tamsui Urban Plan and Chongjian Street.

Throughout this process, local historians, scholars, and architectural professionals in Tamsui have expressed their views through literature, art, and journalism, resulting in the designation of monuments and historical buildings and preventing the destruction of local environments. However, past efforts have focused more on the preservation of physical assets, neglecting the importance of literature, art, and journalism in these endeavours. Whether these elements should be given equal importance to facilitate the sustainable development of cultural heritage is a question worth exploring.

Literature Review

Research on the preservation and historical process of cultural heritage in Tamsui, Taiwan, from the 1970s to the present includes several key studies. Chang (2014) explored the features of the campaigns to reclaim Fort San Domingo, the expansion and preservation of Tamsui Old Street, the campaign to save

Tamsui Little White House, and the north side expressway of Tamsui River. Yin (2013) used the concept of cultural governance to analyse the process of Fort San Domingo's designation as a national monument and its subsequent transformation into the Tamsui Historical Museum, New Taipei City. Chang (2008) examined the relationship between museums and urban development from the perspective of Tamsui Historical Museum management, addressing the challenges of sustainable operation. Hsu (2015) analysed the civic movement for the preservation of Tamsui's cultural heritage from the perspective of public participation and its impact on the overall cultural heritage environment. Chen (2015) discussed the combination of social media and the Chongjian Street preservation movement, and how social media aids in fostering a sense of collective identity within social movements.

However, the aforementioned literature lacks discussion and theoretical analysis of the relationship between the preservation and evolution of cultural heritage and related literature, art, and journalism.

Research Objectives

This study aims to understand how literature and journalism influence the preservation and evolution of the cultural heritage environment in Tamsui by analyzing the following cases: the campaign to reclaim Fort San Domingo, the expansion and preservation of Tamsui Old Street, the campaign to save Tamsui Little White House, the Tamsui River North Expressway movement and Tamsui River Rescue Alliance, and the preservation movements for the Sixth Road of the Tamsui Urban Plan and Chongjian Street.

Theoretical Framework and Research Methods

Theoretical Framework

Michel Foucault posits that historical writing embodies forms of power domination, where the process of trimming, organizing, and simplifying complex historical events and ascribing meaning to them conceals inherent contradictions, fractures, and conflicts (Wright & Rabinow, 1994).

Chen (1995) mentions that "heritage preservation" is an interpretation of history, embedding specific historical assumptions, perspectives, and power relationships. This process is a "production of imagined spaces," creating "differentiated locations" in the real world by utilizing traces left by previous generations to produce "contemporary meanings" that allow for various readings and imaginations. The imaginative production of historical spaces results from different social agents participating in the field of heritage preservation, continually engaging with different historical meanings.

E. E. Schattschneider argues that when groups prepare their interest claims, they form organizations based on these interests, creating a certain political bias. This is because the organization itself is a "mobilization of bias" ready to take action (Schattschneider, 1960, p.30).

Hsieh (2020, pp.85-86) further elaborates on the use of bias mobilization, including "bias formation," "bias operation," and "bias transition". "Bias formation" refers to taking actions that promote the formation of any bias favorable to oneself, which can be viewed as "bias mobilization." "Bias operation" refers to the actual functioning of the formed bias, where the implied interests and losses among relevant actors are activated and exhibit the patterns of "bias mobilization." "Bias transition" indicates that bias is structured

by the existing political-economic context; if it aligns with the characteristics of the supporting political-economic structure and context, it will continue to exist. Otherwise, it will be adjusted or changed by another form of "bias mobilization," leading to the transition of that bias.

Research Methods

This study employs the concept of "the imaginative production of historical spaces," as proposed by Chen (1995), which suggests that the different historical meanings continuously shaped by various social agents involved in heritage preservation result from their participation in this field. Additionally, it utilizes Hsieh's (2020) concept of "bias mobilization," including "bias formation," "bias operation," and "bias transition," to analyze the cases. The primary research methods include:

- Historical Research: This involves analysing the preservation and evolution of cultural heritage in Tamsui, Taiwan, from 1970 to the present.
- Case Analysis: The analysis focuses on the following movements:
  (1). The campaign to reclaim Fort San Domingo.
  (2). The expansion and preservation of Tamsui Old Street.
  (3). The campaign to save Tamsui Little White House
  (4). The Tamsui River North Expressway movement and Tamsui River Rescue Alliance.
  (5). The preservation movements for the Sixth Road of the Tamsui Urban Plan and Chongjian Street.

Results and Discussion

The Campaign to Reclaim Fort San Domingo (1972-1980)

Bias formation

After Taiwan opened its ports in 1860, the British government secured a perpetual lease for Fort San Domingo and its surrounding land in Tamsui in 1867. The British Consulate was established within Fort San Domingo in 1868. However, during the Pacific War, starting on December 8, 1941, the Japanese seized the property as enemy assets in 1942. After World War II ended, the British returned to Fort San Domingo in Tamsui (Chang, 2014).

Following the relocation of the Republic of China (ROC) government to Taiwan in 1949, the ROC announced the severance of diplomatic relations with the United Kingdom in 1950 because the UK recognized the People's Republic of China (PRC). Despite this, the British did not relinquish their perpetual lease on Fort San Domingo. In 1972, when the UK established diplomatic relations with the PRC, it entrusted the management of Fort San Domingo to Australia. Subsequently, after the ROC severed ties with Australia, the UK assigned the custodianship of the fort to the United States. This period saw growing discussions within both government and civil society about the appropriate handling of Fort San Domingo. By 1979, following Taiwan's severance of diplomatic relations with the United States, the issue of reclaiming Fort San Domingo and its surrounding land became a symbol of asserting national sovereignty.

Bias operation

Due to the national sovereignty issues involved in the campaign to reclaim Fort San Domingo, the Taipei County Council proposed the "Reclamation of Fort San Domingo" in 1974. At the same time, voices from

the public advocated for the return of Fort San Domingo to the Republic of China (ROC). In Tamsui, students concerned with local heritage, such as Li Shuangze, Li Liguo, and Sun Jiayang, introduced Tamsui through various media such as painting, photography, and reportage literature. They also conducted numerous interviews with the public to discuss opinions on the ownership of Fort San Domingo. For instance, Li Liguo's book "The Chronicles of Fort San Domingo" (1978) included discussions like "Who Can Manage Fort San Domingo?", "Tamsui Town's Views on Fort San Domingo", "Is It So Difficult to Reclaim Fort San Domingo?", and "Public Opinions on the Ownership of Fort San Domingo".

Fort San Domingo symbolized the reclamation of national sovereignty and the end of China's suffering, representing a break from 19th-century British imperialism. In "The Chronicles of Fort San Domingo," Li Liguo wrote, "You are the forgotten ceded land, severing the emotions of the sunset, gazing up at your face, ah! The sorrow of modern history, the sea conveys your silent regret" (Li, 1978, pp. 7-8). He further remarked, "In reality, Fort San Domingo is managed by the United States with actual sovereignty held by the UK, existing in a vacuum-like environment, visible but inaccessible; but emotionally, in the context of modern China, in the nation's suffering, Fort San Domingo stands very close to us, as if we belong to each other" (Li, 1979, p.135).

Li Shuangze composed a song titled "Fort San Domingo," with lyrics expressing, "Three hundred years of unceasing imperialism took away their splendor and left us with ruins. Fort San Domingo! You are our witness" (Liang, 1978, p.273).

In the poem "The Morning at Fort San Domingo," Yang Du described the campaign to reclaim Fort San Domingo with phrases like "interwoven with sorrow and joy," "a broken family," and "a mother weakened by aggression" (National Taiwan University Civil Engineering Institute, 1983, p.2).

Bias transition

Ultimately, Fort San Domingo was reclaimed by the Republic of China (ROC) government following the severance of diplomatic relations with the United States. It was designated as Taiwan's first historic site under the Cultural Heritage Preservation Act. Through the investigation, research, and restoration plans for the monument, it was transformed into an exhibition space. This event marked the beginning of extensive research and discourse on the history of Tamsui. Local historical and cultural studios, along with scholars dedicated to researching Tamsui, gradually began to emerge.

The Expansion and Preservation Movement of Tamsui Old Street (1993-1999)

Bias formation

In 1978, the comprehensive review of the Tamsui Town Urban Plan in Taipei County primarily aimed to improve traffic issues and pedestrian safety, while also addressing the needs of tourism. This plan proposed widening the original width of Zhongzheng Road, which had been modified during the 1936 Tamsui urban renovation. It also involved the removal of the old street shopfronts along the road, raising concerns about balancing tourism, pedestrian safety, and the preservation of the street’s historical facades (Hsu, 2015, pp.142-143).

Bias operation

The Tamsui Town Office actively participated in the initiative, and the Tamsui Community Studio moved into the old street, proposing alternative plans for street improvement. These plans emphasized a human-centred approach to enhance road traffic conditions and preserve the street's historic facades.

Through the town office's publications, seminars, old photographs, and cultural markets, residents were able to experience walking on the old street and assess the feasibility of developing tourism. The Tamsui Cultural Foundation and planning units became involved, and local neighbourhood organizations were established. They petitioned the then-Governor of Taiwan Province and submitted a proposal to the Tamsui Town Representatives to petition the town office and the widening project's supervisory authority. This effort received positive responses and led to modifications in the street design.

However, a subsequent new town mayor enforced the street widening project, leading to a struggle among old street homeowners, supervisory authorities, and local groups.

Bias transition

Due to the passive inaction of the Taipei County Government, Tamsui Old Street was ultimately widened, leading to the reconstruction or demolition of many old buildings' facades. However, this process initiated the transformation of the surrounding space and environment of Tamsui Old Street, the preservation of its historical appearance, and the revitalization of its local industries. It also marked the beginning of active participation by local residents in the preservation of cultural heritage in Tamsui.

The Campaign to Save Tamsui Little White House (1996-1997)

Bias formation

The Tamsui Little White House, formerly the residence of the Qing dynasty's Tamsui Customs officer, was built in 1875 after the Customs Office purchased land from Tamsui residents. In the 1990s, rumours of its potential redevelopment surfaced. Consequently, on September 27, 1995, the Tamsui Town Office applied to have the Tamsui Little White House designated as a historic site. However, the supervisory authority, the Customs Administration of the Ministry of Finance, raised objections, noting that in April 1995, the Tamsui Little White House had already been approved for decommissioning, with plans to demolish the building and construct a new dormitory complex (Chang,2014, pp.203-205).

Bias operation

This approach sparked concern among local Tamsui groups. The Huwei Cultural and Historical Studio initiated the "Save the Little White House Campaign." Cultural and historical organizations, along with architectural scholars, participated, and national cultural groups joined in signing petitions. They published articles, submitted petitions, and staged protests. Legislators held public hearings to apply pressure on the Ministry of Finance.

Bias transition

Due to the efforts of local residents and academics, the building was preserved and designated as a historic site on February 25, 1997. In 2015, plans to construct a 27-story residential building in front of the

Tamsui Little White House threatened the overall environmental landscape surrounding the historic site. Local groups and residents in Tamsui, dissatisfied with the passive attitude of the New Taipei City Government, launched another "Save the Little White House" petition. This movement garnered enthusiastic support from hundreds of people, urging both the central and New Taipei City governments to recognize the severity of the issue. With advances in technology, image simulations were used to demonstrate the environmental impact to the public. Ultimately, the New Taipei City Government shelved the construction project.

Tamsui River North Expressway Movement and Tamsui River Rescue Alliance (1997-2000)

Bias formation

In 1996, the Taiwan Provincial Highway Bureau proposed the first phase of the "Tamsui River North Side Expressway," planning to construct an 8.2-kilometer long double-layered elevated bridge with three lanes in each direction. Due to its passage through the Tamsui Mangrove and riverbank, local groups believed it would impact the natural ecology of the Tamsui River, prehistoric sites, and cultural heritage, disrupting the relationship between urban life and the waterfront (Hsu, 2015, p.162).

Bias operation

Local civil society organizations in Tamsui argued that the expressway would harm Tamsui's landscape and damage historical buildings along the Tamsui River. During their campaign to revoke the project, they published their own materials and articles in newspapers, inviting experts and scholars to voice their opinions. In 1997, local residents and academia in Tamsui established the "Rescue Tamsui River Action Alliance," garnering support from representatives and local governments. Due to the participation of universities and civil groups, a report on the historical sites was first submitted on April 4, 1998. On January 8, 1999, the Taipei County Government invited experts, scholars, and members of the Rescue Tamsui River Action Alliance, including the Huwei Cultural and Historical Studio, Tamsui Cultural Foundation, Taipei Branch of the Environmental Protection Union, Tamsui Historical Fieldwork Studio, and Tamsui Community Studio, for a joint inspection. By designating historical sites, they effectively halted the construction of the Tamsui River North Side Expressway.

Bias transition

In June 2000, the Taipei County Government announced that the Tamsui Climate Station, Tamsui Seaplane Base, Tamsui Shell Warehouse, and Tamsui Customs Wharf and Warehouse were designated as county-level historic sites, initiating their restoration and reuse. On September 25, 2000, the Environmental Impact Assessment review concluded that the development would affect the mangrove ecosystem, severely impact the landscape, and public transportation, deciding against the development. However, in 2006, the Taipei County Government proposed an alternative plan, the "Tamsui River North Side Surface Road," downgrading the expressway to a city road, with most sections designed as surface roads. In 2009, this plan was submitted to the Environmental Protection Administration for review. The environmental assessment was conditionally approved on April 15, 2011, and the New Taipei City Government began construction in August 2012. During this period, the "Anti-Tamsui North Road Alliance" opposed and protested the project, resulting in multiple design changes. Ultimately, the Executive Yuan approved the construction of the Tamsui North Road on August 6, 2022, with an expected completion date of June 2029.

Preservation Movements for the Sixth Road of the Tamsui Urban Plan and Chongjian Street (2001-2014)

Bias formation

Chongjian Street, the earliest developed street in Tamsui, was divided into two segments in 1981 due to urban planning. The road adjacent to Fuyou Temple was designated as part of Urban Plan Route 6. In 2001, new construction began, which involved the demolition of some old street houses and historical buildings. This sparked protests and expressions of concern from local groups (Hsu, 2015, pp. 172-173). In 2010, the Taipei County Public Works Bureau planned to widen the road in three sections. By 2011, the New Taipei City Government held meetings and decided to proceed with part of the planned road. However, in 2013, they reversed their decision and opted to continue the road widening, leading to policy oscillations (Hsu, 2015, pp. 179-180).

Bias operation

Local residents in Tamsui formed the Community Development Association, and Tamsui Community University initiated workshops and proposed alternative road plans. Efforts were made to promote community cultural asset preservation and the establishment of the Tamsui Street Culture Promotion Association. Due to this issue, local groups and residents began to mobilize forces to protect Chongjian Street. In 2010, some Tamsui residents launched the "Occupy Chongjian Street" campaign, demanding preservation. This movement gained momentum through social media networks.

Additionally, a creative market event was held on Chongjian Street in 2011 to revitalize the street culture. In 2014, the Street Culture Promotion Association organized the on-site "Praise Chongjian Street" event, inviting all lovers of the old street to gather and express their support for cultural preservation to the government.

Bias transition

Due to the numerous opinions from local groups, various departments within the New Taipei City Government adjusted the direction of Urban Plan Route 6. Ultimately, they preserved the original layout of significant road sections and designated surrounding street houses and historical buildings as municipal heritage sites.

Conclusion

Tamsui is an ancient town in Taiwan with a rich historical and cultural landscape and architecture. However, since the 1970s, the pressures of environmental development and tourism have led to the destruction of many valuable streetscapes, riverside environments, and historical buildings. This study analyses the preservation and evolution of Tamsui's cultural assets through the concepts of "the production of imagined space" and "mobilization of bias," focusing on the formation, operation, and transition of biases. The research conclusions are as follows:

Since the 1970s, due to pressures from environmental development and tourism, many valuable street spaces, riverside environments, and historical buildings in Tamsui have been destroyed. However, many local historians, scholars, and architectural professionals have focused on the town's development and future. Through case studies, it has been found that the preservation and evolution of Tamsui's cultural

assets is a process of contention among different stakeholders. By paying attention to and discussing cultural assets, it has been possible to alter the preservation and development dilemma under the pressures of environmental development and tourism.

In the past, the actions to protect Tamsui's cultural assets have shifted from issues of national dignity to the protection of the local living environment. Media mobilization has transitioned from newspapers and articles to social media, and the methods of protection have become more open and inclusive. Under the pressure of urban development and tourism, only through community building, cultural asset preservation, resident participation, and advocacy can the preservation and development dilemma be changed.

For Tamsui to achieve sustainable development, discourse must be formed within the system, but the power outside the system must also be maintained. Literature, art, and reporting can shape a vision of sustainable development, revealing new relationships between history and reality.

Acknowledgement

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Posters

Submission ID: 34

Fostering Sustainability through Art and Culture: Exploring the Impact of Yakshagana.

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Abstract

India's art and cultural wealth stands as indispensable elements intricately woven into the fabric of our nation's heritage over time. Culture plays a pivotal role in the development of any nation, embodying a collective set of attitudes, values, goals, and practices. Its influence extends across various realms, with art and culture evident in nearly all economic, social, environmental, political, educational and other activities. The cultural wealth of India is intricate and diverse, embracing a wide range of traditions and expressions across various facets of art like dance, music, art and craft, culinary traditions, festivals, architectural marvels, literature, textiles, and numerous other elements. To facilitate effective community development, a comprehensive understanding of folk culture, customs, and traditions is imperative.

Folk dances play a pivotal role in India's rich tradition and culture, holding enduring significance. Yakshagana, a traditional theatrical art form originating from Karnataka, a southern state in India, boasts a documented history spanning over 500 years. This powerful medium of folk communication relies on a combination of independent creative elements, including gestures, facial expressions, body movement, costuming, make-up, music, dance, and dialogue. Indeed, Yakshagana literally translates to the "song (gana) of the yaksha (nature spirits)." This paper seeks to analyze and establish connections between the themes of the Yakshagana and the representation of nature spirits, exploring their impact on fostering environmental consciousness.

Yakshagana has been employed extensively as a means of conveying themes related to various societal issues, including health, environment, literacy, family planning, women empowerment, social harmony, and agricultural development. The central focus in leveraging Yakshagana for environmental awareness is to weave storytelling with messages addressing environmental concerns, integrate traditional ecological wisdom, champion green initiatives, and incorporate sustainable practices into performances. The study focuses on a case analysis centered around the narrative titled "Vayu Vijaya" (The Triumph of the Wind). The present research aims to investigate how Yakshagana can effectively promote environmental consciousness through the vibrant medium of Yakshagana, a traditional folklore of Karnataka.

Track 7 Socio-economic Aspects of Sustainable Development

7a. Global Inequality and Poverty

Abstracts

Submission ID: 85

Impact of Air Pollution on Health and Quality of Life of Individuals in Low-To-Middle Income Countries (Lmics): A Review

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Abstract

Air pollution, both indoor and outdoor, threatens the health of millions of people worldwide as it results in significant health-related consequences. In the 2019 Global Burden of Disease study, it was reported that air pollution from fine particulate matter had resulted in 6.4 million premature deaths. Furthermore, air pollution also imposes a significant cost burden on countries, largely Low-to-Middle-Income countries (LMICs), who already suffer from declining health-related quality of life. Disparities in outcomes have only increased as particulate matter concentrations have decreased in developed countries and increased in developing countries. However, research on the consequences of air pollution on health and quality of life has been predominantly largely focused on High-Income Countries (HICs). Few reviews have synthesized the associations between air pollution and health and quality of life in LMICs. We conducted a systematic review of peer-reviewed articles with the aim of summarizing the current research regarding evidence regarding the impact of air pollution on the health and quality of life of individuals in LMICs. Electronic and manual searches were performed until November 2023. From an initial search of the PubMed database and Google online database using the inclusion criteria, we identified 74 articles (50 from PubMed and 24 from the Google database). Upon further screening of these 74 articles, we excluded 24 (32%) studies due to duplicates (n=12), non-English publications (n=4), and abstract-only publications (n=8). Out of these 50 articles, a further evaluation excluded more (n=20) for having not met the current literature review objectives. The final number of studies that were selected for this review was 30. The literature shows that the negative impacts of air pollution on health and quality of life related to LMICs are greater compared to High-Income Countries. However, due to resource limitations, LMICs lack the health resources and medical infrastructure to respond to the global trend of increased air pollution and lower air quality in this environmental crisis. Therefore, well-designed, cost-effective, and monitored inventions are required to combat this crisis. Furthermore, additional research to monitor the air quality of life is required to understand and identify policy changes that can decrease region-specific and population-driven impacts of air pollution.

Submission ID: 276

The Use of Trend and Mathematical Simulation Tools in Participatory Water Management in Brazil – The Necessary Capacity Building of Members of the Hydrographic Basin Committees and Its Application to SDG 6

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Abstract

The National Water Resources Policy in Brazil has enabled a decentralized and participatory water management through basin committees. These spaces bring together community representatives for discussions and decisions related to water resources management, sharing responsibilities with the government. Their duties include approving and monitoring water resources plans, as well as participating in decisions regarding other instruments. To fulfill these functions, it is essential to train committee members, providing them with effective tools such as trend analysis and mathematical simulation models (like QUAL-UFMG and SWAT). These tools allow for the analysis of monitoring data, creation of scenarios, and evaluation of water quality, directly contributing to decentralized and participatory management. There are ten (10) interstate Basin Committees and approximately two hundred and twenty-three (223) state Basin Committees in Brazil. The institutional arrangement involves a high number of different types of representatives, including people with higher education and others with practical experience. By producing scientific data and translating it adequately to civil society representatives in these committees, the aim is to improve the quality of decisions made by them, enhancing qualitative debates and consequently, qualitative decisions as well. Furthermore, Sustainable Development Goal (SDG) 6, which aims to ensure clean water and sanitation for all, aligns with these efforts. Through the use of these tools, especially the ones presented in this study, it will contribute to the training of committee members who will work with integrated water resources management (indicator 6.5.1) and with a more assertive participation of local communities through indicator 6.b.1.

7b. The Future of Employment and Good Work

Abstracts

Submission ID: 40

Common Good HRM & Sustainability-Oriented Innovation

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Abstract

Sustainability-oriented innovation (SOI) involves planned organizational changes in its products, processes, or practices in response to the call for an active role of organizations in tackling environmental and societal challenges and to create and realizing social and environmental value in addition to economic returns. Environmental innovation refers to the introduction of any new or significantly improved product or service, manufacturing process, reform, or marketing solution that reduces the use of natural resources and the release of hazardous materials throughout the business life cycle (Arundel & Kemp, 2009; Carrillo-Hermosilla, del González, & Könnölä, 2009; Kemp, 2010). Following the categorization of Atuahene-Gima (2003), Leitner *et al.* (2010), Chen *et al.* (2014), and Kennedy, Whiteman, and van den Ende (2017), this study classifies environmental innovation into incremental environmental innovation and radical environmental innovation. The former effectively improves the efficiency of the utilization of existing resources, while the latter generates new knowledge and technology to support environmental protection behavior (Kennedy *et al.*, 2017).

Grand challenges such as environmental degradation and social inequality and intranational initiatives such as United Nation's sustainable development goals have led businesses to play a proactive role and adjust their processes in order to address environmental and social challenges. Consequently, in the field of human resource management (HRM), we have been observing the development of concepts such as socially responsible HRM (i.e., recruitment and selection, development, deployment, and release of employees in a socially responsible and economically appropriate manner (Thom & Zaugg 2004)) and green HRM (i.e., increasing employees' environmental awareness and behavior (Renwick *et al.,* 2016)). The concept of common good HRM (CGHRM) is recently been introduced as a paradigm shift in the field. Principles of CGHRM include (1) the contribution of HR in solving societal grand challenges such as climate change, corruption, migration, poverty, or youth unemployment (2) equal and fair employment relationships, (3) providing all business stakeholders with opportunities for "*participation and democratic workplace representation to achieve locally adapted HR solutions"* and (4) "*protecting human needs for employment, which includes security, safety, and meaningful work*" (Aust *et al.,* 2020).

Although previous studies have improved our understanding of common good HRM, we still lack a solid understanding of its performance outcomes. For example, to date, it is not clear how a firm's level of CGHRM fosters innovation. Some researchers have studied the effects of HRM practices and processes on different types of performance but CGHRM as a new concept in HRM is less studied. The firm outcome this paper focuses on is innovation, particularly sustainability-oriented innovation. Although recently some researchers have argued that firms' engagement in sustainable HRM can improve their performance (), the innovation performance and the mechanism through which CGHRM fosters innovation are lacking. Thus, our study closes these gaps in the HR management literature.

Submission ID: 54

At Arm's Length: Migrants, Staffing Agencies and the Commodification of Labour in a High-Income Setting

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Abstract

Precarious work and labour exploitation is a global phenomenon. High-income countries of the welfare state sort are by no means immune to practices that verge on or indeed imply modern slavery. What might differentiate the global North from the global South, however, is that it is still often workers from the latter that are at risk. In parallel to the mounting incidence of non-standard employment – temporary work, zero-hour contracts, fake self-employment etc. – shifts in the relations of employers to their work force seem to pave the way for viewing labour as a mere commodity. This paper is addressed to this issue. It moves beyond the discussion of geographically extended supply chains and the risk for a race to the bottom at the expense of labour in foreign locations; it does so by turning the magnifying glass to settings where labour-intensive production activities take place in the home market. Specifically, it focuses on the role of outsourcing, intermediaries and above all the institutions (in the sense of rules and social norms) that enable dominant firms to turn a blind eye to the fate of contingent workers, thereby contributing to the ongoing normalisation of workforce exploitation also in high-income countries that else have an enviable reputation for decent working conditions.

Using Sweden as an illustrative case, it sheds light on how changes in policies, institutions and the organization of industries might engender or support precarious work as integral to business models (LeBaron, 2021) or even allow modern slavery as a management practice (Crane, 2013). Although it is not necessarily the case that only migrant workers are at risk, our focus is the sourcing of labour from abroad and how this is expedited by intermediaries that take advantage of changes in policy and legislation.

We contribute to discussions on precarious work and sustainable development where the quality of the institutional environment is seen as a key factor (Moussa *et al.,* 2022). Here, SDG 8 and its target 8.5 are particularly salient. However, it is not only formal rules that appear to pave the way for the recruitment of workers who are made to accept working conditions that are not in line with local norms. In addition to the desire or dire need of workers to find more remunerative sources of income than available back home, other processes can be found to be at work.

Submission ID: 281

The Neoliberal University in Germany: A Systematic Review

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Abstract

Universities' neoliberalization has become an influential research lens in management and organization studies. A neoliberal-university-lens offers scholars to use neoliberal-related concepts—such as competition, profit maximization, or growth—to generate innovative insights about managerial and organizational phenomena within academia. Furthermore, insights on the micro level can be investigated (e.g., consequences for academics). Such insights are important because seeing universities decoupled from neoliberalization creates blind spots and distortions. Thus, scholars increasingly use a neoliberal-university-lens to advance research in various areas, including gender studies, managerialism, labor studies, critical management studies, and higher education studies. Research has considered the evolving patterns of the neoliberal university (Aguinis *et al.*, 2020; Bottrell & Manathunga, 2019; Lorenz, 2012) and established its importance for management and organization studies. Nevertheless, different researchers have various, implicit, and often narrow ideas of what characterizes a neoliberal university, where neoliberalization is relevant, and how it matters for universities and their members. Moreover, there is no common terminology concerning the neoliberal university (e.g., 'corporate university', 'academic capitalism' or 'toxic university'). However, "a diversity of approaches and assumptions implies richness" (Blagoev *et al.*, 2023: p. 2). But if approaches and assumptions remain implicit, such diversity can prevent researchers from building integratively on each other's work (Blagoev *et al.*, 2023) and ultimately hinder them from filling research gaps of the neoliberal university.

Therefore, a review is timely, necessary, and valuable to clarify the neoliberal university in Germany, identify its dominant manifestations, and synthesize findings from the existing literature in order to outline future directions. This paper offers the first systematic review of the diverse body of research. The study undertakes this review guided by three questions: (1) what is the current status of the literature on the dominant manifestations of the neoliberal university in Germany? (2) What is the trajectory of its thematic development? (3) What are the implications for future research suggested by my findings?

Established guidelines for systematic reviews when conducting my review (Kunisch *et al.*, 2023; Simsek, Fox, & Heavey, 2023; Tranfield *et al.*, 2003) to make my results reliable, verifiable, and reproducible (Booth *et al.*, 2012). The approach includes several steps was followed. As this is a work in progress paper and I have not yet completed my literature review, it is unfortunately not possible to report the main results at this stage. However, observations on my part have already been made. Firstly, was able to observe that there is no consistent terminology regarding the construct of the neoliberal university. This is also the first contribution: review creates clarity in the field of the neoliberal university. Secondly, can already see that many manifestations of the neoliberal university thwart the Humboldtian ideal. Consequently, the second contribution is: review helps to illustrate the negative effects of a neoliberalized university on the Humboldtian ideal and thereby provide potential transferable results to audiences outside the German university system.

7c. Economic and Financial Innovations for Sustainability Transitions

Abstracts

Submission ID: 30

Where We Have Come from and Where We Will Go: A Literature Review of Sustainability Accounting

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Abstract

The three decades have witnessed the worsening environmental and social situations and at the same time, the rise of a force that goes against that tendency. It is a new branch of accounting –sustainability accounting. Sustainability accounting aims at changing the "game rules" of the business world and in this way influencing business behaviours, to make a concerted effort in the business sector towards a sustainable future. However, there are only a few literature reviews about the thirty years' development of sustainability accounting. This study will thus review the literatures from the early start of sustainability accounting, through its development progress, to reach the current status quo of this field, finding gaps and suggesting research directions. In other words, it will seek to find where we have come from and where we will go.

Sustainability accounting can be divided into two categories. The first one is general sustainability accounting methods. Through devising accounting tools, it takes the additional costs and income that a company's environmental and social activities have into consideration (Mathew 2000, p.189; Gray *et al.,* 1996, p.186; Bebbington and Gray, 2001; Bebbington *et al.,* 2001). Another is specific sustainability accounting methods. It seeks to solve themed accounting issues, such as water, soil, climate and biodiversity (Bebbington *et al.,* 2021, p.122). This study will research the two kinds of methods separately and finds research gaps in the two fields.

Moreover, practitioners have engaged actively in the process of making and implementing sustainability accounting methods, such as the Global Reporting Initiative (GRI), the Science-Based Target Network (SBTN), the Corporate Sustainability Reporting Directive (CSRD), the System of Environmental Economic Accounting (SEEA) and the International Sustainability Standards Board (ISSB) standards. This study will also shed light on these accounting methods in practice and find research gaps and research directions.

This study has the potential of leading to undiscovered gaps and research directions for scholars and practitioners, to create a better future for sustainability and Sustainable Development Goals (SDGs).

Submission ID: 75

Navigating the Maze: Paradoxical Complexities around Materiality in Non-Financial Reporting: A Case Study

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Abstract

The paper aims to identify the paradoxical complexities influencing the reporting of material issues in non-financial reporting and to explore how an organisation manages them. The study uses a qualitative research approach - a single case study with a UK house builder. Using thematic data analysis, it examines the empirical data collected from 35 semi-structured interviews with internal and external stakeholders and from document analysis. The findings showed that in the case of voluntary sustainability reporting, industry-specific context drives the engagement with and focuses on material aspects in non-financial reporting. The study reveals the tensions between the paradoxical complexities that included early adopter position, a lack of understanding of the materiality definition, multiple stakeholders, goal balancing, and issues around the non-financial data quality. The observed responses of the organisation to these complexities were to create a sustainability ethos / inspiring culture, develop a sustainability team, actively manage external stakeholders, and set up materiality determination, data collection and feedback processes. The study adds to the organisational paradox literature by showing that interconnectivity between complexities can be circular and create complexity loops, and/or form a complexities chain. The study offers insight into the possible management responses to and techniques for adapting double materiality reporting processes.

Submission ID: 98

Assuring Sustainability in a New Industrial Revolution

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Abstract

The world is simultaneously facing the aftermath of the second industrial revolution, and a new industrial revolution, facilitated by information technology, which is changing the way markets and economic systems function. Economic efficiency, characterised by supply and demand equilibrium and investments with a return exceeding the cost of capital, crucially assumes an absence of externalities and interdependencies. Sometimes external effects are taken into account by financial mechanisms, and economic instruments, such as charges, taxes, and land use controls; these can be systematic (carbon pricing), or pragmatic (congestion charges). This paper argues that external impacts, positive and negative, are pervasive: the rule, not the exception, with interdependencies intensified by new technologies and networking effects. The impacts of economic activity, and their incidence, can range in scope from the immediate to the wide-ranging, with both spatial and temporal dimensions. Inter-temporal phenomena have proved particularly challenging for sustainable development: what may appear to be a beneficial investment (both in financial terms and the wide social context) in the short-term may prove less worthwhile in the longer-term. This is highlighted by de-industrialisation and its consequences, as the the second industrial revolution runs its course in OECD countries. The response to inter-temporal impacts has typically been ad hoc, highlighting the absence of strategies to cover the life-cycle and legacies of industries. Meanwhile, can the new industrial revolution do better? What mechanisms are needed to avoid repeating the errors of the past, and safeguard wider societal interests into the future? A key issue here is the degree of permanence of institutions and economic actors: a comprehensive and resilient framework is needed to pursue long-term economic efficiency, and hence true sustainability. The purposes of this paper are to highlight the underlying issues, and to identify the elements of a general strategy to address these issues

Submission ID: 119

Problematizing the 'Finance Gap' in Biodiversity Conservation: Discourse Analysis of UNDP and UNEP's Publications

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Abstract

Despite critiques of the neo-liberalization of nature, the dominant proposed solution to address biodiversity loss has been to fill the so-called "finance gap" by increasing private-sector investment in conservation through various market-based instruments. Within the United Nations, the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) have the mandate to collaborate with member countries to find solutions for increasing private finance for biodiversity conservation, in line with targets set by the Kunming Montreal Global Biodiversity Framework (GBF). Yet little is known of how the UNDP and UNEP are grappling with this mandate in practice or how the current focus on privatisation is perceived and conceptualised by these agencies. This research aims to investigate the *problematization* of the biodiversity "finance gap", by analysing over 30 publicly available UNDP and UNEP reports published over two decades, in addition to webinars and online knowledge products concerning biodiversity finance. By using Carol Bacchi's 'What's the Problem Represented to be?' (WPR) method for discourse analysis, this research seeks to examine how is the role of private finance in biodiversity conservation represented and constructed within UNDP and UNEP's reports and knowledge products. Informed by feminist and poststructuralist epistemologies, the WPR method challenges the conventional view that policies address "problems that exist". Instead, the method helps investigate underlying assumptions for "the construction" of the problem, which potentially creates winners and losers due to a focus on particular issues, and more importantly, examining other issues that have received less attention or that have been silenced.

Preliminary findings reveal a shifting definition of 'private sector investment,' expanding from corporate sectors and philanthropy to financial institutions such as banks, insurance and investment companies. While the reports depict an optimistic conservation outcome with increased private investment, they fail to engage in nuanced discussions regarding criticisms or the potential for failure associated with this approach. Additionally, the "tools of government" like regulation are being reframed as finance solutions, and in line with the regulatory capitalism literature there is an observable transition in how the role of government is represented in the reports - from primarily enforcing environmental regulations, towards facilitating favourable market conditions.

Given the pivotal roles UNDP and UNEP have in assisting Global South nations in achieving the goals set out in the GBF, it is critical to understand how their functions may be shaped and informed by the problematization of biodiversity conservation as a finance problem; which subsequently influences global environmental governance and public and private policy responses at national and sub-national scales. This research directly addresses the conference theme of *'Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood'.* It contributes to SDG 14 (Life below water) and 15 (Life on land). The findings will be presented in person using PowerPoint slides to facilitate the discussion.

Submission ID: 130

Innovations for Creative Green Economy: Scope for Growth, Necessary for Nepal's Prosperity

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Abstract

Nepal, with its rich biodiversity and natural resources, more than 45 per cent forest coverage and 23.4 per cent land into protected areas which stands at the crossroads of development and environmental conservation. The contribution of the agricultural sector (agriculture, forestry and fisheries) to the GDP is gradually declining. It was estimated that the contribution of this sector was 23.9 per cent in the country in 2021/22. The untapped endowed with natural beauty and resources, grapples with challenges in transforming its economy into a green and creative force. The green Innovative approaches are pivotal to overcome these challenges and pave the way for a thriving green economy.

The paper used content analysis of policies, innovative technologies and collected best cases which have been utilizing green based products such as fiber and non-timber base forest products. This policy review, including a few thematic cases, explores the innovation deficit within Nepal's policy landscape and emphasizes the imperative role of inventive strategies in fostering the nation's prosperity through sustainable development through various creative green economy evolutions. The incorporation of digital platforms, block chain for transparent supply chains, and the integration of smart technologies in manufacturing processes can revolutionize industries. These innovations not only reduce environmental footprints but also enhance efficiency and competitiveness on a global scale. Furthermore, fostering a culture of innovation and entrepreneurship is vital for Nepal's prosperity.

The government must create an enabling environment that encourages research and development, supports start-ups, and incentivizes green innovations. Collaborations between academia, industry, and government can catalyze the creation and implementation of novel solutions, driving the country towards a creative green economy. In conclusion, addressing weak domain areas through innovative solutions is imperative for Nepal's transition to a creative green economy, in particular, nature-based creative innovations. The technological supports and its adoption at the local communities embracing innovative strategies can propel the nation towards prosperity by harmonizing economic growth with environmental sustainability. The synergy of innovation and sustainability is the key to unlocking Nepal's potential in the global landscape of green economies.

Submission ID: 249

Paddling Canoes to the Moon? Investing in a Carbon-Constrained World

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Abstract

The global community has agreed that climate change represents an existential threat to civilisation and that transition to low carbon energy, transport, industrial, and agricultural systems is a priority, achieving a net zero carbon emissions economy by 2050. While it is agreed that this transition must also support social justice and equity, there is little explicit consideration of how economic systems may need to transform to achieve desired sustainability outcomes. Instead, market-based approaches and economic adjustments are seen as key tools for driving change. The financial sector is critical to achieving this transition through development, growth, and innovation. The world's one hundred largest pension funds represent over USD $17 trillion, with the top ten countries' sovereign wealth funds representing a further $9.23 trillion. This capital is invested in emerging technologies, companies, and sectors to generate returns for investors that support retirement incomes and personal and institutional wealth. This capital determines the energy systems trajectories of countries and regions, the technologies that thrive or fail, and the industrial development pathways we implement.

Achieving a just and sustainable net zero transition requires investment in sectors and markets that are not comfortably aligned with established approaches to investment lifecycles because of their higher risk profiles. Capital flows are also needed into emerging markets and developing economies (EMDEs) – if the transition does not occur in EMDEs, the net zero outcome will fail. Yet traditional investment decision making is constrained by issues that are not just critical but paradigmatic – issues central to the investment world view. These include the nature of regulated fiduciary responsibilities, benchmark expectations and hurdles on investment return requirements, and risk considerations in new markets. An important question is therefore whether the economic tools being leveraged in the net zero transition are sufficient to achieve it, and if not what else is necessary? Further, how can key challenges be overcome? This paper considers the key factors involved in the carbon-constrained (or climate-aligned) investment paradigm of the transition decades to 2050: carbon pricing (emission trading schemes or carbon taxes) and litigation against governments and corporate actors by regulators (for greenwashing and other commercial misbehaviours) and civil society. Literature review of peer-reviewed and grey literature is undertaken across the contextual themes of economic transition and investment calculus, and the results of this analysis are assessed in view of future climate-based macroeconomic scenarios.

The paper argues that the just and sustainable net zero transition is being attempted using tools that are inappropriate for the context. In other words, our responses to climate change are not unlike trying to paddle canoes to the moon. While we need a vehicle and a set of actions (the canoe, the use of paddles), these are not adequate or appropriate for the environment, the context, and the nature of the challenge (not floating on an ocean but leaving an atmosphere and moving through a vacuum). The work is relevant to all SDGs, but especially SDGs 8 (decent work and economic growth), 9 (industry, innovation, and infrastructure), and 13 (climate action).

Submission ID: 257

Towards a Common Definition of Sustainable Finance: A Review on Consensus-Building

Hiu Ching Chung[1], Wanxin LI[1,2]
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Abstract

The world faces tremendous climate and sustainability challenges that necessitate a global, coordinated effort and financing over the next few decades. The Paris Agreement has set a target of limiting warming to 1.5°C (United Nations, 2023), while 193 nations have agreed upon the UN Sustainable Development Goals (SDGs) to achieve by 2030 (United Nations, 2015, 2023). Meeting these ambitious targets by 2030 is crucial to avoid the catastrophic environmental, economic, and social consequences projected by organizations such as the UN and International Rescue Committee.

As most major economies have pledged to achieve net-zero emissions by 2050, the annual investments required are estimated to be around US$9.2 trillion until 2050, totalling US$275 trillion (Mckinsey, 2022). Additionally, transitioning developing countries to sustainability will require a yearly investment of at least US$6.9-7.6 trillion until 2030 (UNCTAD, 2023). However, sustainable financing currently only mobilizes US$0.4 trillion (Kumar *et al.*, 2022), highlighting significant investment gaps. Without sufficient funding, humanity risks failing to realize critical climate and sustainability goals by 2030, 2050, and 2060 (UNCTAD, 2023).

Although sustainable finance has seen growth, there is a lack of agreement among different stakeholders about specific definitions. The World Bank restricts its focus to environmental factors, while the ISO considers a broader range of environmental, social, and governance criteria. Due to this ambiguity, there are difficulties in mobilizing large-scale private capital, which is urgently required.

This study aims to comprehensively analyze the various definitions of sustainable finance in academic literature and reports by prominent international organizations, standards authorities, and governments. A unified definition of sustainable finance that encompasses essential parameters will be proposed by utilizing bibliometric and text-mining techniques to identify areas of agreement and disagreement.

This research seeks to address the lack of consensus surrounding sustainable finance by establishing a shared understanding of key definitional elements. These findings can aid in developing standardized practices, facilitate cross-border investments on an unprecedented scale, and ensure that financial resources are directed towards crucial priority needs. The results will strengthen the policy relevance of creating a shared understanding - a critical factor in attracting the trillions of dollars needed worldwide by 2030, 2050, and beyond to build a sustainable future for all.

Submission ID: 258

From Green GDP to GEP (Gross Ecosystem Product)

Hiu Ching Chung[1], Wanxin LI[1,2]
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Abstract

China's approach to environmental policy has evolved over time. Initially, the focus was on mitigating the negative impacts of human activity on the environment. However, the government has since shifted its focus to incentivizing the creation of positive environmental values. In 2007, the World Bank estimated that air and water pollution costs China's economy $100 billion annually, which is equivalent to 5.8% of the country's GDP. To address this issue, the government launched the Green GDP project, which factors environmental degradation and ecological damages into the evaluation of regional economic growth and government officials' performance. The National Major Functional Zoning Plan and the National Major Marine Functional Zoning Plan were also established to promote a scientific approach to development, especially in balancing the protection and exploitation of the marine eco-environment.

China's marine ecosystems, which include estuaries, wetlands, mangroves, coral reefs, seagrass beds, and islands, face significant threats from human activities, both on land and offshore. While researchers have attempted to map human activities and their impacts on marine ecosystems globally, there is still a lack of understanding regarding the dynamic interactive relationships between these activities and the marine environment. Therefore, a governance approach is essential to build consensus and collective action among stakeholders and improve the balance of eco-conservation, eco-restoration, and development for the territorial and marine ecosystems.

Preserving ecosystems provides many benefits, including nutrients, ecological services, and recreational activities that can improve overall well-being. The government is exploring alternative approaches to quantify development, such as incorporating gross ecosystem product (GEP) into a nature-social-economic accounting system. This approach values the total value of final ecosystem goods and services supplied to human well-being in a given region annually.

Recently, the Central Committee of the Communist Party of China and the State Council announced the comprehensive advancement of the construction of "Beautiful China." The Guangdong-Hong Kong-Macau Greater Bay Area was selected as a pioneer region, experimenting with land-sea integrated development approaches and helping other areas build capacities through knowledge transfer. These initiatives demonstrate the government's commitment to promoting sustainable development and protecting the environment.

Submission ID: 259

Mapping the Evolution of Sustainable Finance: A Bibliometric Analysis

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Abstract

Creating a shared definition of sustainable finance is essential in mobilising the necessary capital to carbon neutrality and sustainable transition development goals. However, different practitioners and standard-setting bodies have varying perspectives on what constitutes sustainable finance. Without a universally agreed definition, there is uncertainty around what exactly qualifies as sustainable investment, increasing uncertainty and ambiguity risk for investors. A vague understanding of sustainable finance opens a greenwashing door for “green”/ “sustainable” projects, which leads to undermining trust in the market and difficulty in regulation.

This project aims to adopt a bibliometric analysis approach to help guide the field towards consensus. This study employed science mapping, network analysis, and text-mining techniques to examine peer-reviewed literature spanning several decades.

The research identifies trends and patterns in the academic discourse surrounding sustainable finance. It sheds new light on the diffusion of ideas within this interdisciplinary domain, revealing the "invisible colleges" that have influenced scholarly conceptualization. Additionally, text mining was used to extract and compare definitional elements to understand how they developed.

The findings offer actionable insights for stakeholders, enabling them to integrate published views into an overarching framework. This supports ongoing standardization processes that help to qualify sustainable investment and regulations. The study also provides evaluative metrics to benchmark influential academic contributions and inform future research priorities.

Collaboration patterns were mapped to indicate where cross-sector knowledge transfer can be improved, and the results are intended to align understanding between researchers, policymakers, and industry to maximize capital mobilization for sustainability.

Overall, this bibliometric analysis makes significant contributions to sustainable finance. It provides a comprehensive view of the conceptual evolution of sustainable finance within the literature, distils common ground to strengthen definition consensus, and supports applied progress towards this critical sustainability financing goal. By enhancing our understanding of sustainable finance, we can better promote sustainable investment and development for a more sustainable future.

Submission ID: 285

Innovative Economic and Financial Practices to Promote Sustainability in the Food Production Chain Based on the Verification of the Impact of Fish Yield on the Gross Profit of Haute Cuisine Restaurant

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Abstract

The case study addresses a crucial issue for organizations in the food and beverage sector, especially those dealing with high-cost ingredients such as fish. Here are some observations on the points raised:

Fish Consumption Trends: A projected increase in per capita fish consumption reflects a global trend towards a healthier diet, which may contribute to the demand for fish- based products. However, the price remains a limiting factor for many consumers.

Cost Management: Cost management is essential to ensure the profitability of a company, especially in a competitive sector like food and beverages. Evaluating the impact of fish yield on the financial results of the organization is fundamental to maintaining the financial health of the business.

Efficiency in the Use of Raw Materials: Analyzing the yield of different fish species is crucial to maximizing efficiency and minimizing waste in food production. This can help reduce production costs and improve profitability.

Sustainability: The case study approach is also aligned with the Sustainable Development Goals (SDGs), especially concerning innovative economic and financial practices to promote sustainability. Reducing food waste and optimizing the use of natural resources, such as fishing, is essential to achieving broader sustainability goals.

Economic Viability: By associating the cost of raw materials with the final product and selling price, the organization can determine the economic forecast of its operations and identify opportunities for optimization and growth.

In summary, the presented case study offers valuable insights into how effective cost management and maximizing resource utilization can influence the financial health and sustainability of an organization in the food and beverage sector.

Submission ID: 316

Understanding Development Dynamics: A Comparative Study of Nepal and Australia

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Abstract

Nepal and Australia, despite their vast differences in physiographic attributes, share intriguing parallels in socio-economic development. This paper aims to conduct a comprehensive comparative analysis of their developmental courses, current models, and the pivotal insights they offer for fostering economic growth, social progress, and sustainable development within each nation. Despite their geographical disparities, Nepal and Australia exhibit remarkable similarities in their socio-economic fabric. Both nations boast similar demographic indicators and economies predominantly reliant on natural resources. Furthermore, recent political transformations in Nepal have resulted in a governance structure akin to Australia's federal political system, enhancing the parallels between the two countries. A subtle understanding of the historical context and influential factors shaping the development paths of Nepal and Australia sets the foundation for this comparative analysis. While Nepal has navigated recent political transitions, both nations share federal governance structures that influence their policy frameworks and developmental trajectories. The examination of demographic, geographic, political, and economic dimensions unveils the intricate interplay of factors shaping the development strategies of Nepal and Australia. Despite varying landscapes, common themes emerge, highlighting the significance of natural resource endowments and governance frameworks in shaping development trajectories. An exhaustive analysis delves into the characteristics of each country's development model, scrutinizing key dimensions such as innovation in agriculture, infrastructure development, human capital investment, IT sector advancements, and governance structures. By dissecting these elements, valuable insights emerge, shedding light on the efficacy of different approaches in driving socio-economic progress. The comparative analysis identifies lessons learned and best practices gleaned from the experiences of both nations. It underscores the importance of context-specific policies, evidence-based decision-making, long-term planning, stakeholder engagement, and international cooperation in achieving sustainable development goals and economic prosperity. In conclusion, this paper offers valuable insights into the diverse pathways to development traversed by Nepal and Australia. It emphasizes the imperative of continuous adaptation and innovation in response to evolving global challenges. Recommendations are provided for policymakers, stakeholders, and development practitioners, advocating for tailored strategies to enhance development outcomes not only in Nepal and Australia but also in other contexts worldwide.

Full Papers

Submission ID: 324

Assuring Sustainability in a New Industrial Revolution

Shobhana Madhavan[1], Robert Barrass[2]
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Abstract

The world is simultaneously facing the aftermath of the second industrial revolution, and a new industrial revolution, facilitated by information technology, which is changing the way markets and economic systems function. Economic efficiency, characterised by supply and demand equilibrium and investments with a return exceeding the cost of capital, crucially assumes an absence of externalities and interdependencies. Sometimes external effects are taken into account by financial mechanisms, and economic instruments, such as charges, taxes, and land use controls; these can be systematic (carbon pricing), or pragmatic (congestion charges). This paper argues that external impacts, positive and negative, are pervasive: the rule, not the exception, with interdependencies intensified by new technologies and networking effects. The impacts of economic activity, and their incidence, can range in scope from the immediate to the wide-ranging, with both spatial and temporal dimensions. Inter-temporal phenomena have proved particularly challenging for sustainable development: what may appear to be a beneficial investment (both in financial terms and the wide social context) in the short-term may prove less worthwhile in the longer-term. This is highlighted by de-industrialisation and its consequences, as the the second industrial revolution runs its course in OECD countries. The response to intertemporal impacts has typically been ad hoc, highlighting the absence of strategies to cover the life-cycle and legacies of industries. Meanwhile, can the new industrial revolution do better? What mechanisms are needed to avoid repeating the errors of the past, and safeguard wider societal interests into the future? A key issue here is the degree of permanence of institutions and economic actors: a comprehensive and resilient framework is needed to pursue long-term economic efficiency, and hence true sustainability. The purposes of this paper are to highlight the underlying issues, and to identify the elements of a general strategy to address these issues.

Prologue

In 1962 Rachel Carson published Silent Spring, a hugely influential work that set out, as never before, the legacy of human "assaults on the environment", in the form of "contamination of air, earth, rivers, and sea with dangerous and even lethal materials" (Carson, 1962, p. 7). These materials were put into the hands of people "ignorant of their potentials for harm", and used "with a lack of concern for the integrity of the natural world that supports all life"; and there remained "very limited awareness of the nature of the threat" (Carson, 1962, p. 11).

Perhaps the most striking feature of the situation so graphically described is that, while the use of harmful substances may appear reckless, serious, largely irreversible, harm was not caused intentionally. Disturbingly, these lethal materials were deployed with good intentions, to increase food production and security. Nevertheless, the truly unintended nature of the consequences does not mitigate their seriousness; on the contrary, it makes matters worse.

As it turned out, Carson's pathbreaking work foreshadowed the emergence of numerous environmental concerns, all of which had their origins in the industrialisation of the economy. They also had in common considerable time-lags between their origins and an understanding of their effects. Looking to the future: can we do better?

Industrial Revolution

The world is simultaneously facing the aftermath of previous industrial revolutions, and a new industrial revolution, facilitated by information technology, which is changing the way markets and economic systems function.

The origins of present-day social and economic systems are conventionally traced back to the phenomenon known as "the industrial revolution". In the subsequent evolutionary process three distinct stages can be identified, with changes in the organisation of production, the development of new energy sources, and communication media. The transitions can be summarised in Table 1, derived from Rifkind (2011, pp. 35-36).

Table 1. Industrial revolutions: defining characteristics

Industrial Revolution	Organisation	Energy source	Communication
First	Factories	Coal	Mass literacy
Second	Large corporations	Oil	Telephony, broadcasting
Third	Polarisation	Renewables	Electronic media, internet

The essence of the second industrial revolution was characterised by Jevons (1931, p.1) as "the search for exact knowledge, and the planning of processes: from the minutia, of manual operations (based on motion-study) to the lay-out of the machinery of a gigantic plant-even of a whole industry throughout the country". This system facilitated massive growth in the productivity of factors of production, and hence in living standards (at least as conventionally measured).

The two earlier industrial revolutions involved reliance on fossil fuel energy, environmentally damaging substances, products and processes, and a general tendency to neglect effects on natural resources. The third industrial revolution may follow a different course, in terms of its relationship with the environment, but meanwhile the full consequences of its predecessors are becoming apparent.

The delayed impacts of previous industrial revolutions are multifaceted, ranging from the local to the global. An instance of the former was the Aberfan disaster of 1966, when a collapsing colliery waste tip killed 144 people, including 116 children. The subsequent enquiry found that little prior thought had been given to the stability of the tip, and it was not subject to any significant legislative or regulatory requirements (Aberfan Tribunal, 1967, p.131). Yet with hindsight the catastrophe appeared inevitable.

Land contamination is a major legacy issue. The UK government website (https://www.gov.uk/contaminated-land) lists examples of contaminants, including heavy metals, oils and tars, chemical substances and preparations, gases, asbestos and radioactive substances, where land has been used for factories, mines, steel mills, refineries, and landfill.

The phenomenon was highlighted by the London Olympic Games in 2012, the site for which required redevelopment of more than 200 hectares of land previously used for chemical and fertilizer works, landfills and depots, with a legacy of severe soil and groundwater contamination (Pollution Solutions, 2012). At the time of the earlier industrial uses, no thought can have been given to the eventual legacy and the implications for future land use.

The most prominent legacy of the earlier, fossil fuel dependent, industrial revolutions, is climate change. The situation is described by Rifkind (2011, p. 23) as follows: "the Entropy bill for the first and second industrial revolutions is coming due. Two hundred years of burning coal, oil, and natural gas to propel an industrial way of life has resulted in the release of massive amounts of carbon dioxide into the Earth's atmosphere".

There has been a considerable time lag between enjoyment of the benefits of the earlier revolutions and the realisation of their wider costs. For instance, the first European Community Environmental Action Programme (1974-77) was to a large extent reactive, focusing on reduction of pollution and nuisances that were the consequence of previous neglect of the environment (European Community, 1973), prioritising measures relating to certain products and industrial sectors, the environmental impacts of energy production, and water quality in the Rhine basin.

There was no mention of climate change. In 1987, ten years later, the European State of the Environment Report devoted less than half a page to the issue. It observed that "although there is some debate" the increase in carbon dioxide emissions since the industrial revolution may have serious consequences, and went on to note that "data on atmospheric concentrations ... are generally lacking" (European Commission, 1987, pp. 142-43).

The key features of the third industrial revolution include decentralisation and globalisation of production and supply chains, a shift from manufacturing to a service- and knowledge-based economy, and online consumption of digitisable products and services (see Coyle, 2021, pp. 196-98). The possibilities for undesirable outcomes (repeating the experience of earlier industrial revolutions), and their avoidance, is the subject of this paper.

Economic Efficiency

As economic structures and institutions evolved, concepts of economic efficiency developed. In the simple model of the market system, the supply and demand equilibrium are efficient and optimal; and investments are undertaken if their return exceeds the cost of capital.

Within this framework, an efficient size of an enterprise depends upon the balance between costs of in-house and outsourced activities. Thus "a firm will tend to expand until the costs of organising an extra transaction within the firm become equal to the costs of carrying out the same transaction by means of an exchange in the open market" (Coase, 1937, p. 395).

In this simple model, costs are in monetary terms defined by prices determined in the markets for factors and inputs, and are borne, directly or indirectly, by the enterprise. Furthermore, the ultimate incidence, as opposed to the magnitude, of costs does not depend on whether or not the activity is outsourced.

If the model is modified to relax this assumption, there could be three elements of cost for the enterprise:

- Costs for which it is advantageous for the enterprise to bear directly
- Costs of activities that are outsourced through transactions at market prices
- Social costs, not subject to market transactions.

One element of cost (or benefit) to the enterprise is perception-related. Reputational risk can be reduced by distancing the enterprise from activities that are socially or environmentally damaging, and thus might give rise to negative impressions. The growing complexity of networks associated with the third industrial revolution has increased the scope for opaque supply chains that diminish risks of reputational damage. Thus, the magnitude of costs in category (3) borne by the enterprise could depend on whether or not the enterprise assumes direct responsibility for them. If the enterprise covers the costs of remedial measures, this would also affect the balance between these costs and the burden of wider impacts not subject to remedial action.

External Impacts

External impacts, positive and negative, are pervasive: the rule, not the exception. Where they are known, and measurable, and are limited to the short-term, economic solutions can, at least in principle, correct the imperfections of the market. When these conditions do not apply, society faced a major challenge.

In the simple market model, an enterprise sets its output to maximise its profit, at the level where marginal revenue, generated from the sale of an additional unit of output, equals marginal internal cost, the cost to the enterprise of an additional unit of output. However, as was indicated above, the costs of production are not necessarily fully incurred (either directly or indirectly) by the enterprise. There can be additional external costs, such that only a proportion of marginal total cost is borne by the enterprise. Those elements of cost that are avoided do not enter into the decisions with respect to the level of output. The financial viability and social justification of various relative cost scenarios are summarised in Table 2.

Table 2. Financial Viability and Social Justification: Scenarios

SN	Scenario	Viable	Socially Justified
1	Marginal Total Cost ≤ Marginal Revenue	Y	Y
2	Marginal Internal Cost ≤ Marginal Revenue ≤ Marginal Total Cost	Y	N
3	Marginal Total Cost ≥ Marginal Revenue	N	N

The socially optimal pattern of output is reached where the costs (including wider impacts) of production begin to outweigh its social benefit. Where the external effects are known, and restricted in scope, an economically efficient solution can be arrived at by a transaction between the polluters and the affected parties. Thus "the right to do something which has a harmful effect (such as the creation of smoke, noise, smells, etc.) is also a factor of production. … The cost of exercising a right (of using a factor of production) is always the loss which is suffered elsewhere in consequence of the exercise of that right" (Coase, 1960, p. 44).

However, the pre-conditions outlined above do not always apply: indeed, they are quite restrictive: "there is no reason why, on occasion, … governmental administrative regulation should not lead to an improvement in economic efficiency. This would seem particularly likely when, as is normally the case

with the smoke nuisance, a large number of people are involved" (Coase, 1960, p. 18). In practice, there are numerous instances where regulators fix permitted levels of substances used in products or released into the environment; and enterprises have to accommodate their productive activities within the regulatory requirements. The outcome is then an approximation to the socially optimum level of output. The resulting output may be zero – as for instance in the case of leaded motor fuel – with technologies adapted to more acceptable alternatives.

Enterprises can be incentivised towards an optimal outcome if they are required to bear the full cost of their activities, and thus take them fully into account when deciding what to produce and at what level of output; hence the frequently cited polluter pays principle. Measures such as planning controls, regulatory penalties, and financial mechanisms such as environmental taxes and charging schemes are utilised to internalise elements of cost that enterprises would otherwise avoid. Sometimes these are systematic (such as carbon pricing), and sometimes pragmatic (such as road congestion charges).

External Impacts in the Third Industrial Revolution

How will the third industrial revolution change external impacts and their incidence? It is clear that new technologies and networking effects have intensified interdependencies. Changes in relative production costs and hence consumer prices, particularly for goods and services that can be delivered digitally, has far-reaching effects.

Hirsch made a distinction between the material and the positional economy. The former embraces physical goods and some services: their distinguishing characteristic is amenability to continuing increases in labour productivity. The positional economy comprises elements that are "either (1) scarce in some absolute or socially imposed sense or (2) subject to congestion or crowding through more extensive use" (Hirsch, 1977, p. 27). The third industrial revolution has seen a flourishing of activities that are scalable, replicable and non-exclusional, such that they give rise to consumption that can be scaled upwards without limit. In contrast, increasing consumption of positional goods and services changes their nature.

Coyle (2021 p. 170) characterises the development of information technology associated with the third industrial revolution as an "economic rewiring"' such that "when the price of a technology declines so much people use it a lot more". Consumption of services that can be delivered electronically has massively increased, as has the use of associated hardware (the now ubiquitous smart phone going in just a few years from non-existent to inescapable). The consequence has been a "long-term structural shift away from manufacturing to an increasingly service-based and knowledgebased economy" (p. 197).

What are the implications for sustainable development? Some familiar pressures are still with us. IT networks require hardware, which has associated environmental impacts, through its production, use and disposal life-cycle. Some of these may intensify: hi-tech equipment requires exotic components such as precious metals and rare earths (some of the latter are listed in Rifkind, 2011, pp.196-97). IT users are often prodigious consumers of energy (it is estimated that annual electricity consumption associated with Bitcoin exceeds that of Norway (Schmidt, 2024)).

More fundamentally, the structural shift does not negate Hirsch's central insight that consumption is constrained in the positional economy. The distribution of rewards of industrial revolutions tends, in the

short-term at least, to be asymmetrical; as Coyle observes "the digital sector … has created extraordinary wealth concentrated in very few hands" (Coyle, 2021, p. 132).

This in turn has implications for consumption, particularly on the part of the beneficiaries of the technological revolution. When the price of a product is reduced, there is both a substitution and an income effect. Price reductions have indeed led to increased usage of goods and services transformed by information technology. This implies that consumers are able to access better products with lower expenditure; they can have more to spend on other types of consumption (an income effect). One consequence might be increased demand for positional goods, with intensification of associated environmental pressures (this type of phenomenon is discussed with reference to reductions in energy prices in Barrass, 2002).

Spatial and Temporal Dimensions

Costs can be spread over time. Typically, capital costs are subject to amortisation, whereby debt repayments are serviced from revenues. Social costs arising from productive activities can accrue with a time-lag; they can also be subject to a degree of uncertainty which increases as the productive activity becomes further removed in time. In principle, this process can be modelled, with probabilities attaching to outcomes and scenarios, so that it would be possible to arrive at some estimate of the "true" marginal cost (in terms of the discounted present value), and apply economic instruments to ensure that this is taken fully in account when enterprises decide the level and composition of their output. This, of course, depends on the modellers' ability to make plausible forecasts, and attach probabilities to the anticipated outcomes.

The temporal separation of productive activities and the accounting for their external costs is shown schematically in Figure 1.

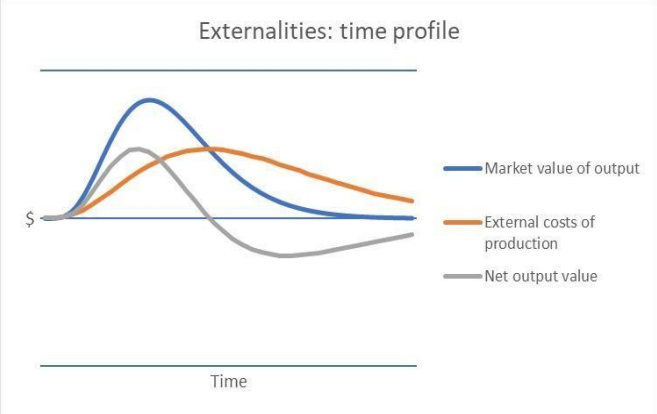

Figure 1. Temporal Separation of Productive Activities and their External Costs

When a product is introduced, its sale generates revenue (the market value of output), and the revenue generated each year increases over time. The annual external cost also rises, but more slowly. Eventually, the annual revenues reach their highest point, and start to decline. However, the annual external cost continues to increase for some time. Eventually it exceeds the annual revenue (the market value of output); even when the revenue has declined to zero, with the product no longer manufactured, external costs persist. The social value, shown by the net output value (market value of output minus external cost) becomes negative, which suggests that production should have ceased much earlier.

The distancing between economic activity and its wider consequences can be both spatial and temporal; and a high degree of spatial separation can tend to delay the reckoning of external costs. For instance, products used in more prosperous neighbourhoods can end their lives in less prosperous areas where waste management is not well-developed (this is discussed, with reference to the shiftability of environmental impacts, in Madhavan and Barrass, 2008, p. 5 et seq.).

Such a process can be seen in the legacy of the earlier industrial revolutions. No calculations were made for the legacy costs, associated with phenomena such as climate change, contamination of land and waters, and hollowing out of communities, either in terms of the probabilities attaching to them, or their present values. Little thought was given to these matters.

As the legacy is now being addressed, the impermanence of institutions and economic actors is evident. The enterprises that were users of fossil fuels are now long gone, or transformed beyond recognition. This can be expected to be the case for any delayed impacts of the third industrial revolution.

Uncertainty

One lesson that can be learned from past failures to anticipate threats to the environment and the quality of life is a need for resilience, in terms of known, perceived, or anticipated threats, challenges, or indeed opportunities. Policy-makers have sought to follow the precautionary principle, whereby such threats can be identified early and appropriate action taken (see for instance EEA, 2001). A distinction is made between risk and uncertainty: the crucial difference being that in the former case probabilities can be attached. Where there is uncertainty, hard evidence of possible harm may be lacking, but there are nevertheless grounds for suspecting that a phenomenon may give rise to damage.

Table 3 sets out a classification of scenarios, depending on what is known (or thought to be know) about their, existence, impacts and probabilities of causing significant harm.

Table 3. Scenarios: Risk, Uncertainty, Suspicion, Ignorance and Radical Uncertainty

Category	Existence	Impacts	Probabilities	
			Known	**Unknown**
1	Known	Known	Risk: preventive action to reduce risk	Uncertainty: action to reduce potential hazards
2	Suspected	Suspected	Suspicion: false knowledge, firmly believed (an unstable state)	Ignorance: Precautionary action taken to anticipate, identify and reduce impacts
3	Unknown and unanticipated	Unsuspected	Not possible	Radical Uncertainty: probabilities are unknowable (and irrelevant) until after the phenomenon is identified

Source: derived in part from Madhavan and Barrass (2007), Table 1 p. 7.

Elements of this table relating to known or suspected impacts were derived from the 2001 EEA report, which did not include the state of "suspicion"; this can occur where probability estimates that have a high degree of subjective judgement are attached to outcomes that are, at best, imperfectly understood (see Madhavan and Barrass, 2007, p. 7).

The present paper adds (Category 3) the possibility of radical uncertainty, where nothing is known or suspected. In such states of radical uncertainty "we cannot attach probabilities because we cannot conceive of these states", so for instance the invention of the wheel was not preceded by speculation on the probability of its invention (Kay and King, 2020, p. 39). In such circumstances the precautionary approach, as envisaged in the EEA report, cannot be followed.

Hitherto inconceivable occurrences are usually considered in terms of singular "black swan" events: "large scale unpredictable and irregular events of massive consequence" which, perhaps ironically, "are in retrospect explainable" (Taleb, 2012, p. 6).

Successive industrial revolutions have seen increasing complexity in economic systems, as supply chains and communication networks become more sophisticated, with intensification of challenges facing policy-makers. As Taleb puts it "the modern world may be increasing in technological knowledge, but … it is making things a lot more unpredictable." This is because "complex systems are full of interdependencies … and non-linear responses" (Taleb, 2012, p. 7).

The non-linearities can result in an impact that is not of great concern, such as pollutants that can be tolerated in low concentrations, becoming over time, and by stealth, a matter of considerable concern (and necessitating substantial remedial expenditures).

Strategies to Address New Challenges

Earlier industrial revolutions ran their course with a mixture of unawareness of, and indifference towards, the wider impacts of the ensuing technological changes. The consequence is a damaging legacy, characterised by Rifkind as the entropy bill. Recent decades have seen a growing awareness of the legacy, and measures to alleviate its damaging effects. A more problematical issue is the ramifications, and potential legacy, of the third industrial revolution.

Are we better placed than our predecessors to anticipate these, to ensure that development is sustainable and bequeaths to future generations a benign legacy? There are reasons to be positive, primarily because, drawing on the experience of earlier industrial revolutions, there is more awareness of potential for harm, with efforts to anticipate and avoid it. On the other hand, the increased complexity of economic systems, characterised by interdependencies facilitated by technological change, may give rise to unprecedented challenges involving radical uncertainty. In short, while the capability to deal with these challenges may have improved, it needs to, because they are increasingly complex.

The challenges can be addressed through a three-fold strategy, comprising:

1. Understanding of the relationship between technology and vulnerability;
2. Awareness of the wider impacts of structural changes;
3. Greater certainty with respect to their outcomes.

The linkage between dependence on technologies and vulnerability (1.) must be acknowledged and better understood. History shows how powerful economic forces favour concentration on a limited range of technologies and production techniques; successive industrial revolutions have seen transitions from small workshops in the first revolution, to large factories in the second, to electronic networks in the third. These have had an economic logic, with increased efficiency and the realisation of economies of scale. However, they have also had a downside in environmental contamination in a variety of forms. The third industrial revolution involves dependence on electronic systems; a failure of critical systems (such as those controlling environmental infrastructure) can have extremely serious consequences. Would vulnerabilities be reduced with greater diversity and resilience?

With respect to strategy 2, awareness of issues, scientific research, and political pressures can, to an extent, improve responses to future challenges. Work is ongoing in many quarters to identify phenomena that may potentially be of major concern; for instance, Diamond (2019, p. 383) lists various possible areas of concern: inequality, conflict, energy, and natural resources.

The third feature of the strategy can be understood with reference to the categorisations in the table above. The objective would be to move issues to higher categories, so that they are better known and better understood, and to the right-hand column so that more is known about the likelihood of significant harm.

Insurance Against the Future

While the strategies outlined above may provide a degree of reassurance against a repetition of past experience, knowledge of the future will always be imperfect, certainly before it becomes the present, and even after it arrives. The question therefore arises as to what safeguards there can be against inherently uncertain negative impacts.

As indicated above, the stretching of impacts over time can be particularly challenging, especially where there is a significant distance between the activities that lead to the impacts and awareness of their effects. There are financial instruments, such as the US Superfund taxes (EPA 2024), that deal with legacy issues and environmental disasters. Nevertheless, the allocation of costs of preventive and remedial measures is often a matter of political bargaining: climate change is a notable instance, where varied instruments have been deployed to promote decarbonisation.

In the case of radical uncertainty, it is not possible to design policies or measures oriented to specific phenomena, simply because we have no idea what the characteristics of an unknown, and unforeseen, phenomenon might be. However, "to say we cannot predict, or specify a probability distribution, is not to say we know nothing about the future" (Kay and King, 2020, p. 326); so we can anticipate that some hitherto unforeseen challenges will arise in future, even if it is impossible to identify them in advance.

Knowing this, it is possible to develop financial instruments to deal with such eventualities. These would be analogous with pension funds and insurance schemes. Some members of a pension scheme will die before reaching the qualifying age, some will die shortly after, and others will enjoy longevity. With sufficiently large numbers, categorisation of individuals is unnecessary. Similarly, insurance is geared to specified eventualities: although it is not known in advance which policy-holders will make a claim, the

number and extent of claims can be predicted with a reasonable degree of certainty. International collective insurance could also help to address issues of equity; this has been a major concern in the context of climate change, both in terms of inter-generational impacts and the disproportionate effects on low-lying regions at risk from rising sea levels.

One possibility is to earmark some of the money in Sovereign Wealth Funds (SWFs) to deal with unforeseeable eventualities. According to the International Forum of Sovereign Wealth Funds there are over ninety SWFs around the world managing $800tn in assets (IFSWF, 2024). Their investment policies have to take account of climate change risks. It is obviously not possible to allow for specific risk in the case of radical uncertainty, but provision can be made for contingent expenditure necessitated by unforeseeable eventualities.

Financial instruments might also be developed through existing international organisations, or under the auspices of a Global Environmental Organisation (this was envisaged by Donald Esty (1994, pp. 78-98) in the context of world trade negotiations, but its proposed remit could have been extended to environmental "fire fighting" as unknowns become knowns).

Conclusion

The subject of this paper, assuring sustainability in a new industrial revolution, is complex and multifaceted. It relates to what is known, what is not known, and what we might get to know. A transition towards greater knowledge and understanding will involve a great deal of research, across many fields.

The overall focus should be on awareness of the wider implications for sustainable development. This was a conspicuous deficiency in the earlier industrial revolutions, and dealing with the legacies is a matter of continuing study and debate. Meanwhile, the full effects of the third industrial revolution, driven by electronic technologies, are subject to varying degrees of uncertainty.

Some supply-side impacts, and behavioural changes are already evident, and issues such as effects on land use, transport and communication, natural resources are already the subject of study.

Other implications of the transition, and any contemporaneous exogenous developments, are subject to considerable uncertainties, and consequently are more difficult to assess. The best approach here is to be open-minded, avoiding group think, and develop wide-ranging scenarios that can then be the subject of further study to improve assessment of risks and to narrow the degree of uncertainty.

Radical uncertainty constitutes a challenge that is, in a literal sense, impossible. Something that is unknown, and unsuspected, cannot be researched. Nevertheless, it is possible to put in place systems to prepare institutions and measures to address eventualities that are unforeseeable (although they may often appear, with hindsight, eminently foreseeable). The requirements for such systems, and their implementation, could well be a fruitful area for research.

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Track 8 Social Foundations of Sustainability

8a. Gender, Inclusivity and Human Rights

Abstracts

Submission ID: 114

Women's Role in Corporate Governance for Scaling ESG in Kenya's Banking Sector

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Abstract

The study investigates the participation of women in the corporate governance of commercial banks in Kenya by understanding their profile as directive board members, and their potential in advancing ESG practices implemented by the banks. Governance literature demonstrates a relationship between women's participation in corporate governance and ESG practices. Other literature shows ESG practices are emerging in sub-Saharan Africa. Therefore, our study builds on these two knowledge contributions. The study uses a mixed methods approach in two consequent phases. The first phase involves a quantitative analysis of the descriptive statistics of board compositions of banks listed on Nairobi Securities Exchange (NSE). The integrated and ESG/sustainability reports of banks are used to understand the state of the art of women´s participation in corporate governance and consequently to select 6 cases for further analysis. The second phase of the study uses the case studies identified in the first phase to analyze the role women play as board members in advancing the ESG practices in their respective financial institutions by using qualitative data collection methods, specifically interviews and document analysis. Preliminary findings show that women are represented in board level positions among Kenyan banks. The analysis of the ESG and/or sustainability reports demonstrate that commercial banks provide substantial ESG disclosures and use well established sustainability reporting frameworks. The relationship between women participation in boards and their influence on the ESG practices used by commercial banks is yet to be shown by the study. These preliminary research findings may have implications for both policymakers and practitioners (especially bankers and investors). Commercial bank boards that purposefully include women directors, could perform better in terms of ESG disclosures. The results may also present criteria for identifying women´s leadership profile and call for an increment in the proportion of women´s participation in the corporate governance of African banks. Commercial banks represent important capacity for scaling impact targets of the Sustainable Development Goals (SDGs), as they provide critical resources to implement and scale initiatives with positive environmental and social impacts. Banks that include women in positions of corporate governance might implement better ESG disclosure practices or improve their potential to scale sustainable finance assets, and consequently enhance progress of SDG targets achieved at a country level. This study examines the relationship between women´s participation in banks' board structures and their effect on ESG implementation. This study builds upon advances in literature that confirms women´s participation in corporate governance of banks as an influencing factor of ESG implementation, and considers findings that identify leadership of board members, as drivers of ESG. This study evaluates the state of the art of women´s participation in commercial banks in Kenya and develops leadership profiles of women´s board members, as references for increasing gender diversity in the corporate governance of banks.

Submission ID: 221

Redefining Mobility: An Ethnographic Study of Women's Experiences of Daily Travel in Kathmandu

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Abstract

In Nepal, there is a lack of comprehensive understanding of women's experiences and challenges related to daily travel in urban areas. This research gap limits the consideration of gender-specific needs in urban planning and decision-making processes, resulting in a lack of policies and interventions to address women's mobility concerns.

This ethnographic study aims to bridge this gap by investigating the daily travel experiences of women in Kathmandu and redefining the concept of mobility from their perspective. The research questions guiding this study are as follows: How do women's mobility experiences in Kathmandu intersect with other aspects/roles of their lives, such as employment and care-giving responsibilities? What challenges do women face while navigating the urban mobility in Kathmandu? What mobility solutions are effective in addressing these issues? And what are the policy and practice implications of the findings?

The study employs in-depth interviews with women representing different backgrounds and roles in Kathmandu. By collecting qualitative data through these methods, the research has gained insights into the daily mobility patterns, experiences, and challenges faced by women in their various roles, including as workers, caregivers, and active members of their communities.

Drawing upon existing literature on gender and urban mobility, this research utilizes qualitative research techniques such as empathy mapping to explore the intersecting factors that shape women's mobility experiences in Kathmandu. The data collected from participant diary studies and interviews are analyzed thematically to identify recurring themes, challenges, and potential solutions. The findings are then presented and discussed in focus group discussions with participants from diverse backgrounds.

In summary, this ethnographic study seeks to redefine mobility by exploring women's experiences of daily travel in Kathmandu. By considering their diverse roles, challenges, and aspirations, the research aims to inform the development of gender-responsive urban policies, enhance the design of inclusive mobility infrastructures, and create more equitable and sustainable urban environments in Kathmandu and beyond.

Keywords: *women's mobility, urban transportation, gender equality, ethnography, gender-responsive urban planning, inclusive mobility*

Submission ID: 264

A Sociological Evaluation of Problems Encountered by Women Related to Disasters and Disaster Locations

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Abstract

Disasters and gender issues have been scrutinized separately for quite a long time. When we look at their considerations together in the literature, it is closely linked to vulnerability issues. However, recently these evaluations revolved around risk evaluations concerning the shift in disaster management to risk management approaches. Due to the gradual increase and expansion of the impact areas and dimensions of disasters, the necessity of increasing the studies to be carried out on disasters has come to the fore. Although disasters have left their deepest traces on vulnerable groups. Due to the social construction of women's relations with society, they are affected by disasters in different dimensions, and there is an increase in the dimensions of vulnerability that already exist in post-disaster environments. Although disasters are natural, they can turn into hazards depending on the coping capacity of societies. Female individuals, who are already present in the social sphere and are vulnerable to dangers, have come to light in disaster situations with their roles and relationships in social life. In the relational analysis of the disaster with female individuals, it has come to an important point to address the issue due to the unpreparedness of women for disasters, their difficulties in accessing resources in all processes of the disaster, their security problems, and social problems. In the relational integrity of disaster and women's studies in national and international literature; It has been seen that it is associated with the framework of concepts such as vulnerability, hopelessness, victimization, and helplessness. Due to the socio-economic status of women in society, a situation has emerged that works against them in the face of disasters, causing them to face many other problems, especially security, in disaster and post-disaster processes. To understand present situations, it is necessary to adopt a sustainability approach and accept disaster issues as processes combined. Recent experiences reveal these necessities.

This study, which is limited to national and international literature studies, is aimed to evaluate the problems experienced by women, who are one of the vulnerable groups in the society, in the face of disasters. In the study, firstly, the theoretical framework related to disasters will be evaluated then the relationship between disasters and women's problems and risks will be mentioned. At the end of the study; the security risks and problems of women related to disasters will be evaluated in the light of the accessed existing worldwide literature. The findings will be evaluated on the grounds of derived perspectives from recently experienced international and Turkish examples. Hangün's special M.A study on women's experiences after the Kahramanmaraş and Elazığ earthquake in Elazığ and Öner's distinction on different experiences, risks, and present conditions of nearby different locations related to disasters sets important grounds for discussions.

The findings reveal that it is necessary to study gender-related problems by taking gender, sustainability, and process perspectives at the core of future studies to understand, evaluate, and summarize their situations, problems, risks, and solutions properly by considering disasters and disaster locations.

Submission ID: 282

Quilombola Women and Environmental Racism in Brazil: Non-Extractive Research Supporting Communities

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Abstract

The paper aims to examine the protagonism of quilombola women fighting against community problems related to social and environmental rights in Brazil. Qualitative research based on the history of oral testimonial tradition was carried out, in the context of two Quilombola Communities in Brazil. The researchers adopt the Engaged Research approach using non-extractive methodologies of research. We try with this research strategy to support the protagonism, autonomy, and centrality of the communities fighting for rights.

A study was carried out in the Quilombola Community of Arturo's and Ribeirão, the first being located in the city of Contagem, and the second in the city of Brumadinho, both in the state of Minas Gerais, Brazil. Arturo's quilombo was chosen because it is the first community recognized as Intangible Heritage in the state of Minas Gerais, which occurred in 2014, and the second quilombola community in Ribeirão for having suffered the effects of the collapse of the Córrego do Feijão mining dam in Brumadinho, which took place on January 25, 2019. Oral tradition history comprises living narrators and is based on issues from the past, to maintain myths and traditions, which are passed from generation to generation. Narrative analyses aim to find experiences, with practices being the phenomenon to be investigated. In these authors' view, the temporal, social, and physical context are the basis for a narrative study. These authors intersect the temporal, interactional, and contextual dimensions and relate them to the experience of each research subject.

Quilombo is understood as: "groups of escaped slaves; expressions of cultural and political resistance; ethnically and culturally differentiated social groups; collective identity processes and more new subjects of sociocultural rights." (Rodrigues, 2010). The condition of quilombola women outside their territory is one of discrimination, due to their condition of being a woman, they suffer from sexism, racism, social class, and quilombola stigma. These oppressive attributes add up, providing triggers for greater prejudice by a sexist and racist society. Still, they do not overlap, but permeate each other, leading to disempowerment, which is why black quilombola women are more concentrated at the base of the economic pyramid, due to low education and work most of the time as a domestic worker. However, within quilombos women are empowered and take on roles in fighting for better living conditions, and are recognized and respected. Quilombola women are matriarchs, queens of the Congado, a traditional Brazilian religion and cultural manifestation, they take charge of the needs of the quilombola people, such as obtaining public transport for children, obtaining income, guaranteeing the culture and memory of traditional peoples. This study can be a starting point for greater debate in academia and, thus, move beyond theory to the daily lives of black people, going beyond the record in history, enabling black people to have the right to citizenship and Quilombos to become communities where the Environmental Racism no longer exists.

Full Papers

Submission ID: 169

Gender-Inclusivity under the Plurality of Hindu Law: A Study on the Need of Importance and the Rights in Architecture

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Abstract

The environment and the society remain consistent and sustainable, if it is shaped with the combination of different individual mindsets and abilities. One of the key elements of sustainable society is gender equality. This paper is based on the sustainable approaches and the design considerations for gender, inclusivity and human rights in architecture, as women do face many challenges because of the society. This paper is based on the systematic content analysis which utilizing the various secondary data collection sources, including visual surveys, literature study, journals, interviews and the case studies. This study focuses on the different challenges and the discriminations faced by the women because of the gender inequality and the deriving strategies to mitigate them. It also focuses on the design parameters and approaches taken to make women more secure and safe. In conclusion this research extends beyond analysing the challenges and the law and policies stated by the Indian Government for the women and defines about how gender is framed and how facilities are to be provided. This paper also defines how women can achieve better work environment in terms of architecture and also focus on the execution, designing, planning and orientation of the spaces to create a better and safe environment for them.

Introduction

Imagine an architectural landscape that not only embodies aesthetic appeal but also stands as a testament to gender equality, ensuring that every individual, regardless of gender, feels equally represented and valued. The environment and society remain consistent and sustainable if they are shaped by a combination of different individual mindsets and abilities. Sustainable societies are defined as structures that include different elements in a balanced way to remain healthy over the long term. Societies are basically the backbones of human civilization and one of the key elements of a sustainable society is gender equality. The most important elements within society are gender, which is caused by the different roles given to male and female members. In this era, society introduces gender issues and women's rights as problems of sustainability.

Gender is a socially constructed system of dynamic differences as well as an innate source of fixed and universal male and female differences (Hanson, 2010). This problem is caused by many aspects, architecture being one of them. Architecture effectively promotes gender equality in a society through its impact on the built environment by creating a better work atmosphere.

Aim of the Study

Design is crucial for creating sustainable societies, yet the intersection of design and gender remains underexplored. This study investigates how gender influences the built environment and its role in

sustainability. Designers, tasked with crafting socially sustainable spaces, might be guided by gender considerations in their choices of layout and functionality. On the user side, gender influences how people experience and interact with spaces, affecting their perceptions of comfort and attractiveness.

Literature Review

Creating an inclusive and effective work environment requires a comprehensive and thoughtful approach that integrates numerous factors, including restroom facilities, workstations, meeting rooms, lighting, acoustics, accessibility, safety, and the design of windows and doors.

Table 1. Planning, execution, designing and orientation of spaces in a built environment

ASPECT	PLANNING	EXECUTION	DESIGNING	ORIENTATION
Restroom facilities	Plan gender-neutral restrooms.	Build with privacy partitions.	Use inclusive symbols and signage.	Central, well-lit locations (e.g., near main lobbies and corridors).
Workstations and offices	Plan flexible workstations.	Execute ergonomic designs Use adjustable furniture.	Combine open and private spaces. Adjustable desks and chairs.	Balance collaboration and privacy, maximize natural light (e.g., large windows, skylights).
Meeting rooms	Plan various sizes Ensure accessibility (e.g., wide doors, ramp access).	Build with flexible partitions and sound proofing (e.g., movable walls).	Include inclusive technology (e.g., video conferencing, hearing loops).	Locate away from noise sources. Ensure easy access and visibility.
Lighting and acoustics	Plan adjustable lighting. Plan for noise reduction.	Install dimmable fixtures. Use sound absorbing materials.	Incorporate acoustic panels, reduce glare and eye strain (e.g., anti-glare screens).	Enhance natural light use. Position noisesensitive areas wisely (e.g., quiet zones).
Accessibility features	Plan comprehensive access. Include accessible parking and entries.	Build ramps, elevators, wide corridors. Install assistive technologies (e.g., hearing loops, and automatic doors).	Tactile indicators, visual cues. Use contrasting colors for navigation (e.g., color-coded floors).	Integrate access features seamlessly (e.g., ramps incorporated into main design).
Safety and security	Include inclusive safety protocols (e.g., regular drills, clear instructions).	Strategic lighting and cameras (e.g., well-lit pathways, cameras in key areas).	Secure entry points and exits (e.g., keycard access, emergency exits).	Ensure easy emergency access (e.g., clearly marked exit routes).
Windows and doors	Plan for appropriate window and door sizes (e.g., large windows for light, wide doors for access).	Build with standard dimensions for accessibility. Use automatic or easy-to-open doors.	Use large windows for natural light. Ensure doorways accommodate all users.	Orient windows for light and ventilation. Position windows to enhance views and light.

To begin with restroom facilities, it is crucial to design gender-neutral restrooms equipped with privacy partitions to ensure both comfort and security for all users. Inclusive symbols and clear signage should be utilized to make these facilities easily identifiable, accommodating a range of needs and ensuring that everyone feels welcome. The positioning of these restrooms in central, well-lit locations, such as near main lobbies and corridors, is essential for guaranteeing easy access and high visibility, thus promoting inclusivity and convenience for all users. Moving to workstations and offices, planning flexible workstations that include ergonomic designs with adjustable furniture is key to enhancing comfort and productivity. Adjustable desks and chairs should be provided to cater to varying needs and ensure that all employees can work comfortably. A balanced mix of open spaces for collaboration and private areas for focused work is necessary, allowing employees to choose between interaction and solitude based on their tasks and preferences. Maximizing natural light through large windows and skylights contributes to creating a bright, inviting atmosphere that supports both well-being and productivity. This approach ensures that workstations are adaptable, comfortable, and supportive of diverse needs, fostering an environment that enhances overall efficiency and job satisfaction. When designing meeting rooms, it is important to plan for various sizes to accommodate different group needs and ensure accessibility by incorporating wide doors and ramp access.

Flexible partitions and soundproofing features, such as movable walls, should be used to create adaptable spaces and minimize distractions. Including inclusive technology, such as video conferencing systems and hearing loops, supports diverse communication needs, making meetings more effective for everyone involved. Positioning meeting rooms away from noise sources is crucial for maintaining a quiet atmosphere conducive to productive discussions. Ensuring that these rooms are easily accessible and visible further promotes convenience and inclusivity, facilitating participation and collaboration. Effective lighting and acoustics are fundamental to a comfortable and productive work environment. Planning for adjustable and dimmable lighting solutions allows for customization based on tasks and personal preferences. Enhancing natural light through large windows and skylights helps to create a brighter and more welcoming workspace.

Addressing acoustics involves incorporating sound-absorbing materials and acoustic panels to reduce noise disturbances and strategically positioning noise-sensitive areas, such as quiet zones, to maintain a peaceful environment. Reducing glare with anti-glare screens and improving overall lighting conditions contribute to a comfortable and productive workspace. Comprehensive accessibility features are essential for creating an inclusive environment. This includes planning for accessible parking spaces and entries, and ensuring ease of movement within the workspace with ramps, elevators, and wide corridors. Installing assistive technologies, such as hearing loops and automatic doors, supports diverse needs. Using tactile indicators and visual cues aids navigation, and applying contrasting colours, like color-coded floors, enhances wayfinding.

Seamlessly integrating these accessibility features into the overall design ensures they are both functional and aesthetically pleasing, making the space comfortable and navigable for all employees. Safety and security measures are also critical in fostering a secure work environment. Inclusive safety protocols should be developed, including regular drills and clear instructions to prepare all employees for emergencies. Enhancing security with strategic lighting and cameras in key areas helps to monitor and safeguard the workspace. Entry points and exits should be secured with keycard access systems, and emergency exits must be clearly marked and easily accessible to facilitate quick evacuation if necessary.

Finally, the design of windows and doors should focus on maximizing functionality and accessibility. Large windows should be planned to improve natural light and ventilation, creating a more open and pleasant environment. Wide doors are necessary for easy access, and automatic or easy-to-open mechanisms should be used to accommodate all users, including those with disabilities. Positioning windows to enhance both light and views contributes to a bright and welcoming atmosphere. Ensuring that doorways and windows are designed with accessibility in mind helps to create a space that is functional, inviting, and comfortable for all employees. By integrating these elements thoughtfully, a workspace can be created that not only supports productivity and comfort but also fosters inclusivity and safety, ultimately leading to a balanced and effective work environment that meets the diverse needs of all employees. This holistic approach ensures that every aspect of the work environment contributes to an atmosphere of well-being, efficiency, and satisfaction, thereby enhancing overall job performance and employee morale.

Objectives of the Study

The study aims to transform the built environment into a more supportive and equitable space for women by focusing on four key objectives. These objectives explore how architectural and design principles can address gender-specific needs, overcome existing barriers, and create inclusive workspaces. Each objective is framed within the context of the built environment to emphasize its impact on creating better workplaces for women.

Explore the Importance of Gender Equality for Enhancing Work Environments in the Built Environment

The first objective centres on understanding how gender equality can enhance the built environment within architectural practice. In the context of the built environment, gender equality involves designing spaces that are equally accessible and supportive for all users, regardless of gender. This objective aims to investigate how integrating gender-sensitive design principles into architecture can lead to more equitable and functional workspaces for women.

Gender-inclusive design in the built environment can include features such as gender-neutral restrooms, inclusive office layouts, and flexible workspaces that accommodate diverse needs. For instance, openplan offices with adaptable spaces can support various work styles, including those that accommodate both collaborative and solitary tasks. Additionally, thoughtful spatial planning that considers safety and accessibility can improve women's experiences in the workplace. Well-lit pathways, secure entrances, and accessible facilities contribute to a more supportive environment, enhancing safety and comfort.

By exploring these principles, the study will illustrate how gender equality in design contributes to creating work environments that support women’s productivity and well-being. The goal is to demonstrate how architectural design can actively promote a more equitable and functional built environment.

Examine Current Discriminatory Policies and Legal Issues Affecting Women in the Built Environment

The second objective focuses on identifying and analysing discriminatory policies and legal challenges within the built environment that impact women. Discriminatory policies can affect various aspects of architectural practice and the design of workspaces, potentially creating barriers to equal participation and advancement for women.

In the built environment, discriminatory policies may manifest in the form of biased design practices or inadequate regulations that fail to address women's specific needs. For example, a lack of consideration for women's safety in building design or insufficient accommodations for work-life balance can create unwelcoming or unsafe environments. Legal issues might include the absence of regulations mandating gender-inclusive design features or insufficient protections against harassment and discrimination in workplace settings.

The study will examine these policies and legal challenges to understand how they impact the built environment and, consequently, the experiences of women in architectural spaces. By reviewing current regulations, consulting with industry experts, and analysing case studies, the study aims to provide recommendations for policy improvements and legal reforms that address these barriers and promote a more inclusive built environment.

Assess How Inclusive Design Enhances Safety and Well-Being for Women in the Built Environment

The third objective is to assess how inclusive design contributes to safety and well-being for women in the built environment. Inclusive design principles focus on creating spaces that address the specific needs of all users, with particular attention to enhancing safety and comfort for women.

In architectural practice, inclusive design can involve incorporating features that improve safety, such as well-lit areas, secure entry points, and accessible facilities. For example, designing buildings with clear sightlines and effective lighting in both public and private areas can reduce the risk of harassment and increase overall safety. Additionally, creating spaces that accommodate work-life balance, such as breastfeeding rooms or flexible workstations, can enhance women's well-being and productivity.

By evaluating successful examples of inclusive design in the built environment, the study will identify how these design elements contribute to a safer and more supportive workplace for women. The findings will provide evidence-based recommendations for integrating inclusive design principles into future architectural projects to better support women's needs and enhance their overall experience in the built environment.

Demonstrate How Gender-Inclusive Practices Improve the Work Environment for Women in the Built Environment

The final objective aims to demonstrate the benefits of implementing gender-inclusive practices within the built environment. Gender-inclusive practices can significantly improve the work environment by creating spaces that are supportive, equitable, and conducive to women's success.

This objective involves showcasing real-world examples of gender-inclusive practices and their impact on the built environment. For instance, architectural firms that adopt practices such as mentorship programs, flexible work arrangements, and family-friendly policies can create workspaces that better support women. Design features like adjustable desks, collaborative areas, and wellness spaces contribute to a more inclusive and productive environment.

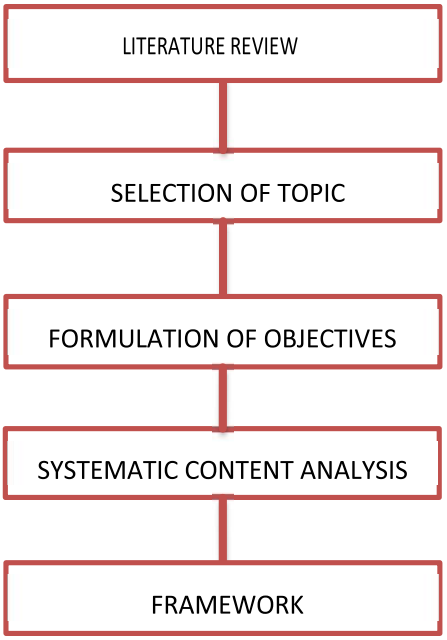
By presenting case studies and success stories, the study will highlight how these practices lead to improved workplace dynamics, increased employee satisfaction, and enhanced career advancement opportunities for women. The goal is to illustrate how gender-inclusive practices in the built environment can foster a more supportive and equitable workplace, encouraging other organizations to adopt similar practices.

In summary, the study's objectives aim to enhance the built environment to better support women through inclusive architectural design. By exploring the importance of gender equality, examining discriminatory policies, assessing the impact of inclusive design, and demonstrating the benefits of gender-inclusive practices, the study seeks to provide valuable insights into creating more equitable and supportive workspaces.

The ultimate goal is to advance the field of architecture by promoting built environments that not only address the needs of women but also actively support their growth and success. Through a comprehensive analysis of these objectives, the study hopes to contribute to the development of workspaces that are inclusive, functional, and conducive to the well-being of all users, particularly women.

Methodology

To achieve a better work environment for women, this study adopts a systematic and methodical approach characterized by meticulous planning and execution. The methodology is designed to uncover how architectural design can significantly impact the creation of safe, inclusive workplaces that cater specifically to the needs of women.



The initial phase of the methodology involves an extensive literature review. This review encompasses a wide range of sources, including academic journal articles, industry reports, and existing studies related to gender inclusivity in work environments. The goal is to gather comprehensive insights into current trends, challenges, and successful strategies employed in various contexts. By synthesizing this information, the study aims to identify gaps and formulate clear, targeted objectives that address the unique needs of women in the workplace.

Following the literature review, the study proceeds to the definition of specific objectives. These objectives serve as the guiding principles for the research, ensuring that the focus remains on aspects most relevant to improving work environments for women. The objectives are designed to be both actionable and measurable, providing a framework for assessing the effectiveness of proposed interventions and solutions.

Central to this methodology is the use of secondary data collection methods. This includes a thorough analysis of existing literature, review of relevant journal articles, and interviews with key stakeholders. Interviews are conducted with experts in architectural design, workplace safety, and gender inclusivity to gather qualitative data that complements the quantitative findings from the literature. This mixedmethods approach enables a comprehensive understanding of how architectural elements can influence workplace dynamics and employee experiences.

Case studies form the cornerstone of the analysis. These case studies are selected based on their relevance to the study's objectives and their demonstrated success in creating inclusive work environments. Each case study is analyzed using systematic content analysis, which involves a detailed examination of architectural features, design principles, and their impact on workplace inclusivity. The case studies provide practical examples of how thoughtful design can address common challenges faced by women in the workplace, such as safety concerns, accessibility issues, and the need for supportive spaces.

The findings from this analysis underscore the pivotal role of architectural design in fostering safe and inclusive workplaces for women. The research highlights specific design strategies and features that contribute to creating environments where women can thrive. These findings are expected to offer valuable insights for architects, employers, and policymakers seeking to improve work environments through design.

In conclusion, this methodology ensures a rigorous and comprehensive approach to understanding and addressing the needs of women in the workplace. By integrating literature reviews, targeted objectives, secondary data collection, and case studies, the study aims to provide actionable recommendations for enhancing work environments through effective architectural design. The ultimate goal is to create workplaces that not only support but actively promote the well-being and success of women.

Results and Discussion

Discriminatory Policies and Legal Issues

The inclusivity of workplaces is critical for ensuring equality and well-being for all employees. However, many workplaces still lack essential facilities and accommodations for women, leading to discomfort and discrimination. This oversight not only undermines gender equality but also impedes productivity and employee satisfaction. Addressing these gaps through thoughtful design and policies is essential for fostering a supportive and equitable work environment. Ultimately, investing in inclusivity benefits the organization as a whole, driving innovation and creating a more positive workplace culture.

Table 2. Discriminatory policies and legal issues with some architectural aspects:

Discriminatory Policy	Legal Issues	Architectural Design Issues	Architectural Improvements	Strategies for Improvement
Lack of separate restrooms	No mandate for separate restrooms in many buildings.	Inadequate women's restrooms on each floor.	Plan and build separate restrooms for women on every floor.	Building and Other Const. Workers (Regulation of Employment and Conditions of Service) Act, 1996
Limited maternity facilities	Insufficient emphasis on workplace childcare facilities.	Absence of nursing and childcare rooms.	Designate rooms for nursing and childcare facilities.	Maternity Benefit (Amendment) Act, 2017
Inadequate safety measures	Poor implementation of workplace safety measures.	Poor lighting, lack of secure access points.	Install better lighting, surveillance, and secure access points.	Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013
Lack of accessible facilities	Disability laws not fully integrated with workplace design regulations.	Inaccessible restrooms and workstations for disabled women.	Build accessible restrooms, ramps, and workstations.	Rights of Persons with Disabilities Act, 2016
Insufficient break areas	No requirements for adequate break areas for women.	Lack of comfortable and private break areas.	Create comfortable and private break areas for women.	Factories Act, 1948
Poor ventilation and lighting	No specific regulations ensuring adequate lighting and ventilation for women.	Insufficient natural light and ventilation in women's areas.	Ensure adequate natural light and ventilation in all areas.	National Building Code of India

Discriminatory Policy	Legal Issues	Architectural Design Issues	Architectural Improvements	Strategies for Improvement
Inadequate toilet design	No standards for toilet design accommodating women's needs.	Poor ventilation, lack of sanitary product disposal, inadequate cleaning.	Design toilets with proper ventilation, sanitary disposal units, and regular cleaning schedules.	Swachh Bharat Mission guidelines, National Building Code of India
Lack of ramps and staircase accessibility	Limited legal enforcement for accessible infrastructure.	Ramps and stair cases not designed for accessibility, making it difficult for women with disabilities.	Build accessible ramps and design staircases with handrails and proper dimensions.	Rights of Persons with Disabilities Act, 2016
Inadequate CCTV surveillance	Lack of mandatory CCTV coverage in critical areas.	Poorly planned CCTV placement, leading to blind spots and unsafe zones.	Install comprehensive CCTV coverage with monitoring in all critical areas.	No specific act, guided by workplace safety regulations

Ensuring inclusivity and safety in the workplace is crucial for fostering a supportive and equitable environment for all employees. However, many workplaces still face significant gaps that disproportionately affect women and individuals with disabilities. These gaps often stem from outdated policies, inadequate architectural designs, and insufficient implementation of existing regulations. This discussion highlights several key areas where improvements are needed and proposes solutions to address these deficiencies.

One of the most pressing issues is the lack of separate restrooms for women in many buildings. This problem highlights a discriminatory policy that fails to adequately meet women's needs. The absence of a mandate for separate restrooms often results in insufficient facilities, with women's restrooms not available on every floor. While the Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996, provides some general guidelines, it does not specifically mandate the inclusion of gender-specific facilities. Consequently, architectural designs frequently overlook the necessity for separate, well-equipped restrooms for women, leading to inadequate planning and a lack of privacy and security. To address this issue, architectural designs should be updated to include separate restrooms for women on each floor. These restrooms should be equipped with proper ventilation, sanitary disposal units, and a regular cleaning schedule to ensure a comfortable and hygienic environment. Updating building codes to enforce these requirements will not only enhance privacy and safety but also align with modern inclusivity standards, supporting gender equality in the workplace.

Another significant gap is the limited availability of maternity facilities in workplaces. This issue reflects an insufficient emphasis on supporting childcare and nursing needs, despite legal requirements. The Maternity Benefit (Amendment) Act, 2017, mandates provisions for maternity benefits, including adequate facilities for nursing and childcare. However, many workplaces still lack designated rooms for

these purposes, leading to discomfort and inconvenience for nursing mothers. To address this shortcoming, it is essential to design and designate specific rooms for nursing and childcare within workplaces. These rooms should offer privacy, comfort, and necessary amenities to support nursing mothers and young children. Implementing these provisions will not only comply with legal requirements but also foster a more supportive and inclusive work environment, promoting gender equality and employee well-being.

Inadequate safety measures in workplaces is another critical concern. Poorly implemented safety measures, including insufficient lighting and a lack of secure access points, can create unsafe environments, particularly for women who may be more vulnerable to harassment and security risks. The Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013, underscores the importance of safe working conditions, yet many workplaces fail to meet these standards. To improve safety, it is crucial to install better lighting, enhance surveillance systems, and secure access points throughout the workplace. These measures will help create a safer and more secure environment for all employees, not only complying with legal requirements but also fostering a culture of respect and security. Prioritizing safety contributes to overall employee well-being and productivity, promoting a sustainable and inclusive work environment.

Accessibility is another area where many workplaces fall short. The incomplete integration of disability laws with workplace design regulations often results in inaccessible restrooms and workstations, creating significant barriers for disabled employees. The Rights of Persons with Disabilities Act, 2016, mandates accessible infrastructure but is not always effectively implemented. To address this issue, workplaces should prioritize building accessible restrooms, ramps, and workstations that adhere to universal accessibility standards. These improvements will enhance the comfort and mobility of disabled employees, supporting their full participation in the workplace. By making these changes, workplaces will not only comply with legal obligations but also promote an inclusive and equitable environment, aligning with broader goals of accessibility and equal opportunities.

The insufficient provision of break areas for women is another issue that requires attention. Many workplaces lack comfortable and private spaces for rest, which results from the Factories Act, 1948, setting general standards without specific requirements for women's needs. This gap means that women often do not have access to designated areas where they can take breaks comfortably and privately. To remedy this, workplaces should create dedicated break areas that offer comfort and privacy, including amenities such as ergonomic seating and quiet spaces. These improvements will enhance overall wellbeing and productivity by providing a supportive environment for women to recharge during the workday. Ensuring adequate break areas aligns with modern standards of workplace inclusivity and promotes a healthier, more balanced work culture.

Poor ventilation and lighting in workplace areas, particularly those designated for women, can negatively impact health and comfort. This issue arises from the lack of specific regulations mandating adequate lighting and ventilation. Although the National Building Code of India provides guidelines for these aspects, they are not always effectively implemented. To address this, it is essential to ensure that all workplace areas, including those for women, are equipped with proper natural lighting and ventilation systems. Designing spaces that maximize natural light and airflow will create a healthier and more

comfortable environment. Adhering to these standards will not only improve the quality of the workplace but also align with sustainable building practices, promoting overall employee well-being.

The design of workplace toilets is often inadequate, failing to meet women's specific needs. Common issues include poor ventilation, lack of sanitary product disposal units, and irregular cleaning schedules. Although the Swachh Bharat Mission guidelines and the National Building Code of India provide frameworks for sanitation and hygiene, these standards are frequently overlooked. To address these deficiencies, it is essential to design toilets with adequate ventilation, proper sanitary disposal units, and a consistent cleaning schedule. These improvements will ensure a clean and comfortable environment that meets the specific needs of women. Implementing these standards will enhance hygiene and contribute to a more inclusive and respectful workplace, fostering an environment that promotes the well-being and dignity of all employees.

Inadequate accessibility features, such as ramps and staircases, reveal gaps in legal enforcement for accessible infrastructure. Often, these features lack necessary dimensions and handrails, making navigation difficult for individuals with disabilities. The Rights of Persons with Disabilities Act, 2016, mandates accessible infrastructure but is not always effectively implemented. Constructing ramps that meet accessibility standards and designing staircases with appropriate handrails will enhance mobility and safety for disabled employees, ensuring they can access all areas of the workplace with ease.

Adhering to the Act's requirements will support an inclusive environment and align with broader goals of accessibility and equal opportunities.

Finally, inadequate CCTV surveillance due to poor planning often results in significant blind spots and unsafe zones. This insufficiency compromises security, despite general workplace safety regulations emphasizing effective surveillance. To address this issue, it is essential to install comprehensive CCTV systems that cover all critical areas and ensure continuous monitoring. This approach will enhance security, deter potential misconduct, and create a safer environment for all employees. By implementing robust surveillance measures, workplaces can better protect their staff and comply with best practices in workplace safety, fostering a more secure and trustworthy environment.

In conclusion, addressing these architectural and policy gaps is crucial for creating a more inclusive, safe, and supportive workplace. By implementing the proposed improvements and aligning with legal standards, workplaces can enhance employee well-being, support gender equality, and contribute to sustainable development goals. This approach fosters a more equitable environment and promotes a culture of respect and inclusivity for all employees, ensuring a healthier and more productive work environment.

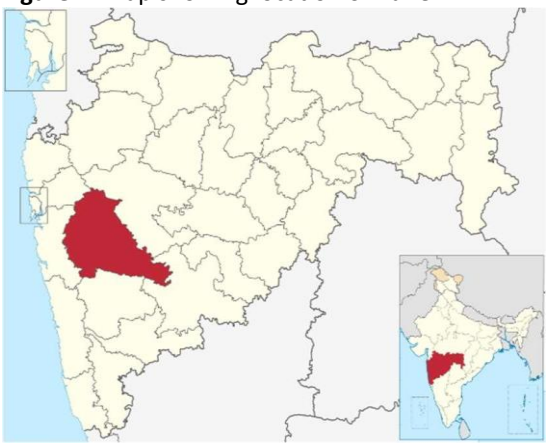
Case Study

Infosys Pune Development Center (Phase 2)

It exemplifies design for a better work environment for women in India

The Infosys Pune Development Center (Phase 2) exemplifies a model inclusive workspace with dedicated women's restrooms, maternity facilities, robust safety measures, and accessibility features, setting a benchmark for modern, gender-sensitive workplace design.

Figure 1. Map showing location of Pune



Source: https://www.google.com/

Figure 2. View of Building

Source: https://www.infosys.com/

Table 2. Study of different architectural aspects

Architectural Feature	Architectural Steps Taken	Benefit to Women
Safety and security	Extensive CCTV surveillance. Well-lit pathways and parking lots. Secure access control systems.	Increased safety and reduced risk of harassment.
Accessibility	Universal design principles. Ramps, elevators, and wide corridors. Accessible restrooms on every floor.	Improved accessibility and mobility for women with disabilities.
Dedicated facilities	Women-specific restrooms. Lactation rooms with privacy and storage. Gender-neutral restrooms.	Enhanced comfort and convenience, supporting work-life balance.
Privacy and comfort	Private work pods and phone booths. Quiet rooms for relaxation. Ergonomic furniture and flexible workstations.	Reduced stress and increased comfort, promoting productivity.
Inclusive communal spaces	Open-plan offices. Inclusive communal areas and break rooms.	Promoted collaboration and inclusivity.
Wayfinding and signage	Clear signage for all facilities. Intuitive wayfinding systems.	Improved ease of navigation and convenience.
Training and mentoring spaces	Designated mentoring and training rooms. Well-equipped conference rooms.	Supported career development and equal opportunities.
Health and wellness facilities	On-site gym and fitness center. Wellness rooms. Healthy food options in cafeterias.	Promoted overall wellbeing and work-life balance.
Emergency preparedness	Clearly marked emergency exits. Regular emergency drills. Emergency response plans.	Enhanced safety and preparedness for emergencies.
Flexible working areas	Hot-desking options. Adjustable workstations for standing or sitting.	Enhanced flexibility and comfort, accommodating diverse work styles.

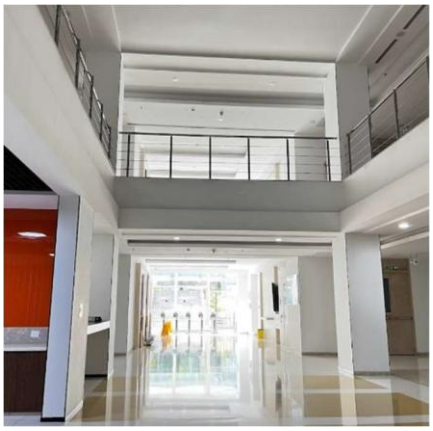


Figure 3. Interior view
Source: https://www.infosys.com/

Figure 4. Image showing adjustable furniture
Source: https://www.infosys.com/

The Infosys Pune Development Center (Phase 2) exemplifies a forward-thinking approach to creating a supportive and inclusive work environment for women through thoughtful architectural design and carefully planned facilities. Each feature has been meticulously designed to address specific needs, thereby enhancing safety, accessibility, comfort, and overall well-being.

One of the most significant aspects of the center's design is its emphasis on safety and security. The implementation of extensive CCTV surveillance across the premises, combined with well-lit pathways and parking lots, ensures a high level of security. Secure access control systems further mitigate the risk of unauthorized entry, creating a safer environment for all employees, particularly women who may be more vulnerable to harassment. This robust approach to security not only enhances personal safety but also fosters a sense of reassurance and trust among employees.

Accessibility is another critical feature of the center, reflecting a commitment to universal design principles. The inclusion of ramps, elevators, and wide corridors ensures that all areas are easily accessible, particularly for women with disabilities. Accessible restrooms on every floor further support this commitment, making it easier for all employees to navigate the workplace comfortably. This focus on accessibility enhances mobility and inclusivity, ensuring that everyone can perform their duties effectively without facing physical barriers.

Dedicated facilities are a standout feature of the development center, providing women with specific amenities designed to enhance comfort and convenience. Women-specific restrooms are strategically placed throughout the building, offering a higher level of privacy and hygiene. Additionally, lactation rooms are equipped with privacy and storage, supporting nursing mothers by providing a comfortable and secure space to tend to their needs. Gender-neutral restrooms cater to all employees, promoting an inclusive environment that respects diverse gender identities. These dedicated facilities support worklife balance and ensure that women's specific needs are met with sensitivity and respect.

Privacy and comfort are integral to the workplace design, with various features aimed at reducing stress and enhancing productivity. Private work pods and phone booths offer a quiet, distraction-free space for

focused work or confidential conversations. Quiet rooms are available for relaxation and mental rejuvenation, providing employees with a peaceful retreat from the demands of the workday. Ergonomic furniture and flexible workstations contribute to physical comfort, accommodating different work styles and preferences. These elements together create a more pleasant and productive work environment, fostering employee well-being and satisfaction.

Inclusive communal spaces are designed to promote collaboration and a sense of community among employees. Open-plan offices facilitate interaction and teamwork, breaking down traditional barriers and encouraging spontaneous collaboration. Inclusive communal areas and break rooms offer spaces for employees to connect and socialize, further enhancing the workplace culture. This design approach supports a collaborative and inclusive environment, where all employees can feel engaged and valued.

Wayfinding and signage are carefully considered to improve navigation throughout the center. Clear signage for all facilities and intuitive wayfinding systems ensure that employees can easily locate essential areas and amenities. This attention to detail enhances convenience and reduces confusion, contributing to a smoother and more efficient work experience.

Training and mentoring spaces are also integral to the center's design, supporting career development and equal opportunities. Designated mentoring and training rooms provide a dedicated environment for professional growth and skill development. Well-equipped conference rooms facilitate effective meetings and collaborative sessions, enabling employees to participate in ongoing learning and development opportunities. This focus on career advancement helps ensure that all employees have access to the resources they need to succeed.

Health and wellness facilities are an important aspect of the center's design, promoting overall wellbeing and work-life balance. An on-site gym and fitness center offer employees the opportunity to maintain physical health and manage stress. Wellness rooms provide a space for relaxation and recuperation, contributing to mental and emotional well-being. Additionally, healthy food options available in cafeterias support a balanced diet and encourage healthy eating habits. These facilities collectively support a holistic approach to employee wellness, recognizing the importance of physical and mental health in achieving a balanced and productive work life.

Emergency preparedness is a critical component of workplace safety. The development center includes clearly marked emergency exits, regular emergency drills, and well-defined emergency response plans. These measures ensure that employees are prepared for potential emergencies and can respond quickly and effectively. This proactive approach to emergency preparedness enhances overall safety and ensures that employees can work with confidence, knowing that their well-being is a top priority.

Finally, flexible working areas are designed to accommodate diverse work styles and preferences. Hotdesking options allow employees to choose their workstations based on their daily needs, promoting flexibility and adaptability. Adjustable workstations that can be used for both standing and sitting enhance comfort and ergonomics, catering to different work habits and physical needs. This flexibility contributes to a more dynamic and adaptable work environment, supporting employees in finding the most effective and comfortable way to perform their tasks.

In summary, the Infosys Pune Development Center (Phase 2) exemplifies a comprehensive approach to designing a workplace that prioritizes safety, accessibility, comfort, and overall well-being. Through its thoughtful integration of architectural features and dedicated facilities, the center sets a high standard for creating an inclusive and supportive work environment for women and all employees. This design approach not only meets immediate needs but also contributes to a positive and sustainable workplace culture, reflecting commitment to both employee welfare and organizational excellence.

Conclusion

Gender inclusivity in workplace architecture is pivotal for fostering balance, productivity, and overall job satisfaction. By integrating features such as on-site daycare, flexible workspaces, and gender-neutral restrooms, organizations can significantly enhance the professional and personal lives of their employees, particularly women. These design elements not only address specific needs but also contribute to creating an environment where all employees can thrive.

On-site daycare facilities are particularly beneficial as they alleviate the challenges faced by working parents, particularly women, who often juggle professional responsibilities with childcare duties. By providing accessible childcare options within the workplace, companies reduce the stress and logistical hurdles associated with balancing work and family life. This convenience allows employees to focus more effectively on their roles, leading to increased productivity and job satisfaction.

Flexible workspaces are another crucial aspect of gender-inclusive architecture. The ability to choose between different work environments—whether hot-desking, remote work options, or adjustable workstations—accommodates diverse work styles and personal needs. Such flexibility is instrumental in supporting employees varying work preferences and physical needs, thereby enhancing their comfort and efficiency. This adaptability contributes to a more dynamic and engaging work environment, where employees feel empowered to perform at their best.

Gender-neutral restrooms further underscore a commitment to inclusivity, providing safe and accessible facilities for all employees, regardless of gender identity. This thoughtful design fosters a respectful and supportive workplace culture, ensuring that everyone has equal access to essential amenities without facing discomfort or discrimination.

Inclusive workplace design also plays a vital role in attracting and retaining a diverse workforce. By prioritizing features that support gender inclusivity and overall well-being, organizations demonstrate a commitment to equality and respect. This, in turn, enhances their reputation as employers of choice, capable of drawing in top talent from a wide range of backgrounds. A diverse workforce, nurtured by an inclusive environment, is better positioned to drive innovation, collaboration, and overall organizational success.

Tata Consultancy Services (TCS) in Chennai exemplifies the positive impact of gender-inclusive workplace architecture. The integration of on-site childcare, wellness centers, and flexible workspaces at TCS not only addresses the specific needs of female employees but also enhances their overall job satisfaction and

retention. By providing these amenities, TCS fosters a supportive and equitable work environment, reinforcing its commitment to gender inclusivity and employee well-being.

Overall gender-inclusive architecture is essential for building a more equitable and successful workplace. By incorporating features that support work-life balance, flexibility, and accessibility, organizations can create an environment where all employees feel valued and empowered. Ultimately, investing in gender-inclusive design not only meets immediate needs but also promotes long-term success and sustainability for both employees and organizations.

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Addressing Gender-Related Disparities in STEM Education for Students Ages 15-18

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Abstract

The fields of Science, Technology, Engineering, and Mathematics (STEM) within education sector have become pivotal for innovation, economic growth, and societal progress. However, a persistent issue hinders the full realisation of the potential of STEM disciplines: gender-related disparities among students aged 15-18. Using 2022 Programme for International Student Assessment (PISA) data, the research reveals significant differences in performance and enrolment rates between male and female students. This is also widely discussed in many countries including France. To further investigate the observed disparities and gather more detailed information on students' experiences and perceptions of gender disparities in STEM education, a quantitative survey was conducted among French high school students aged 15 to 18. The results suggest that male students tend to be more confident in their STEM abilities, which may contribute to their higher enrolment rates in STEM subjects. In addition, the findings highlight societal norms, stereotype threat and the lack of female role models in STEM.

Introduction

In the ever evolving and fascinating landscape of education, the fields of Science, Technology, Engineering, and Mathematics (STEM) have become pivotal for innovation, economic growth, and societal progress. However, a persistent issue hinders the full realization of the potential of STEM disciplines: gender-related disparities which refer to the unequal representation and achievement of male and female students within these relevant subjects. While some countries have made some efforts to reduce this gender gap, it remains a long-standing issue prevalent in educational institutions in several countries, with variations in the severity of disparities. For instance, in France, only 25% of new entrants in engineering, manufacturing and construction degree programs were female in 2019 (OECD, 2021), contributing to the under-representation of women in STEM fields and a lack of female role models. While they can have an impact from the earliest age on elementary school pupils, these disparities take root at the crucial stage of secondary school, where teenagers aged 15 to 18 are the first to be affected by these stereotypes and bias, which undermine women's self-confidence (Gonzalez *et al.*, 2021).

STEM careers are often seen as the jobs of the future, as they promote innovation, and sustainable growth in the world driven by technology and digitalization (World Economic Forum, 2023). Therefore, addressing the enrolment and completion gap in STEM subjects is essential to foster an inclusive, diverse, and innovative workforce, in line with the principles of social justice and equality, ensuring that all students have equal opportunities to pursue their interests and talents. This more equitable and diverse STEM workforce will, in turn, lead to greater innovation and advancements in science and technology.

Literature Review

STEM Education and a Student's Academic Journey

The term "STEM" was officially introduced by the U.S. National Science Foundation in 2001, although it was originally coined in the mid-20th century as nations emphasise the importance of scientific and technological advances to economic and societal progress (Penprase, 2020). STEM education has grown in importance in the 21st century when governments and educators around the world have begun to recognise it as essential to national performance, economic growth, and consequently to social wellbeing (Marginson, *et al.*, 2013). This understanding has led to a global consensus on the significance of STEM disciplines in equipping students with the skills needed to navigate an increasingly technology-driven world. To drive innovation and enhance technology in their future careers, students acquire a wide range of skills during their education journey from early childhood learning to higher degree (Gonzalez & Kuenzi, 2012). Nevertheless, the crucial transition phase from secondary school to higher education in a student's educational journey plays a fundamental role in choosing a STEM career, as students aged 15-18 begin to shape their career aspirations and acquire fundamental knowledge in these disciplines (McClure, *et al.*, 2017). In science, teenagers aged 15-18 develop critical thinking, experiment design, data analysis, evidence-based conclusions, and problemsolving skills (Bybee, 2011). In technology, they gain proficiency in digital tools, software applications, and a deeper understanding of technology's societal impact, paving the way for responsible and ethical technology problem-solving use (Brooks-Young, 2017). In engineering, students explore design thinking, problem-solving prototyping, and interdisciplinary collaboration to create and optimize systems (Harwell, *et al.*, 2016). Finally, in mathematics, they enhance mathematical proficiency, logical reasoning, and quantitative analysis skills to apply models to real-world scenarios (OECD, 2019).

Overall, while STEM disciplines may appear distinct, they share common skills such as cognitive, technological skills and collaboration and communication skills (Educación & Boon Ng, 2019), which transcend boundaries to adhere to the scientific method, involving observation, hypothesis design and testing, experimentation, and analysis (Benz, 2019). Therefore, STEM workforce in future could be mainly decided in high school, between the ages of 15 and 18, where they will begin to acquire their STEM knowledge.

Gender Disparities in STEM Education

As recently as October 23, 2023, a massive one-day strike took place in Iceland to draw attention to the persistence of gender pay gaps, disparities in managerial positions and gender-based violence, despite Iceland's reputation as a world leader in gender equality (Bryant, 2023). This recent event highlights the urgent need to examine and address the disparities between men and women in certain areas of work and society. Women are indeed under-represented in the STEM sector. According to EU research on the growing gender gap in the digital industry, men hold three times as many technology and engineering degrees as women do, just 17% of specialists are women, and women make 20% less money than men (European Commission, 2020). As this under representation begins in education and continues in the workplace where society is becoming increasingly digitized (Rueda, *et al.*, 2021), this gender disparity calls for reflection on its causes at high school level.

Despite making up half of the student population, women remain a minority in many STEM programs (Cheryan, *et al.*, 2017). It has been noted that women prefer to choose careers in fields related to people, their care, and their education, whereas men prefer practical and technical fields (Merayo & Ayuso, 2022). Nevertheless, beyond the straightforward description of what they prefer, it is also vital to identify what influences and conditions the motive and, consequently, the choice made. First, cultural, and societal factors play a significant role in perpetuating the gender gap in STEM. In some countries, disparities between men and women are more pronounced due to cultural norms and expectations regarding gender roles and career choices (M.-T. & Degol, 2017). As a result, gender disparities in STEM education are not uniform across countries, leading to international gender disparities in STEM careers. Scandinavian countries like Sweden and Norway have made significant progress in reducing gender gaps in STEM participation. Norway for instance has steadily improved its gender parity score to 87.9%, climbing to the 2nd position in this year's index (World Economic Forum, 2023). However, other countries continue to struggle with these disparities (Stoet & Geary, 2018). In France for instance, only 36% of the students in the final year of high school in 2020 studying mathematics, physics and chemistry were girls (INSEE, 2022).

Influencing Factors Widening the Gender Gap

Several studies emphasize that gender disparities in STEM are not only about enrolment numbers but also about confidence and self-efficacy. Adolescent girls often face lower self-confidence (OECD, 2019), influenced by a lack of female role models in STEM (Hyde, 2008) that persists. Indeed, studies consistently emphasise the importance of exposure to successful women in STEM fields which can significantly influence girls' career aspirations and motivation (Stoet & Geary, 2018).

Furthermore, negative stereotypes and societal biases can discourage girls from pursuing STEM fields and can thus affect their confidence and self-perception (Leslie, Cimpian, Meyer, & Freeland, 2015). These stereotypes can influence peers, and parents shaping girls' attitudes toward STEM. Indeed, peer influence is powerful during adolescence, and stereotypes can shape the attitudes of both male and female students in STEM. When prevailing stereotypes suggest that STEM is predominantly for boys, girls may experience subtle or overt exclusion from STEM-related discussions or activities by their peers (van der Vleuten, Steinmetz, & van de Werfhorst, 2018). In addition, as primary caregivers and role models, parents have a major influence on their children's career choices and educational aspirations (Olmos-Gómez, *et al.*, 2021). Therefore, when parents hold stereotypical beliefs that STEM fields are more suited to boys, this can influence their expectations for their daughters' career paths.

Addressing these influences is crucial to reducing gender-related disparities in STEM education and ensuring equitable opportunities for all students. It is therefore essential to understand these dynamics in order to formulate effective strategies to bridge the gender gap in STEM education and promote equity. More specially, the following research questions need to be addressed:

What is the current state of the gender gap in STEM education?

How does parental influence impact the academic enrolment and performance of female high school students aged 15-18 in STEM fields and their career choices?

Methodology

Data from the Programme for International Student Assessment (PISA) 2022, a global study is used in this study. PISA is managed by the Organisation for Economic Co-operation and Development (OECD), an international organization that promotes policies to improve the economic and social well-being of people around the world. PISA assesses the knowledge and skills of 15-year-old students in a variety of subjects, including science, mathematics and reading, focusing on their ability to solve complex problems, think critically, and communicate effectively (PISA, 2015). In 2022, the PISA assessment was implemented in 81 countries and economies involving 690 000 students (OECD, 2023).

The PISA database includes information on student performance in mathematics, reading, and science as well as comprehensive data on family context, encompasses factors such as parental education and occupation, family structure, socioeconomic status, access to educational resources at home, and parental involvement in a student's learning. This assessment can also be used to analyse students' behaviours and trends in their environment (Yu & Jen, 2023).

Data was exported from the PISA free access database into an Excel spreadsheet and Power BI was used for descriptive analysis to create key performance indicators. Based on this analysis, the study used anonymous survey to further investigate the observed disparities and gather more detailed information on the experiences and perceptions of students regarding gender disparities in STEM education.

Results and Discussion

To evaluate students' skills and knowledge, the PISA assessments use proficiency scales divided into levels. Scores are scaled to fit approximately normal distributions, with OECD country means around 500 score points and standard deviations around 100 score points (OECD, 2023). About two-thirds of students across OECD countries score between 400 and 600 points. Scores above 700 points are rare, with less than 2% of students, on average, reaching this level. Based on this assessment, the 2022 results highlight a global decline in student performance in mathematics, and science. Indeed, the average mathematics performance score in OECD nations dropped by a record 15 points between 2018 and 2022.

France is no exception to this trend. Indeed, France's performance in 2022 was among the lowest ever measured by PISA, with average scores in mathematics declining compared to 2018 and science scores remaining like 2018 (OECD, 2023). The proportion of top performers (Level 5 or 6) and low performers (below Level 2) in France was similar to the OECD average across both subjects. However, there are notable differences in gender performance, with boys outperforming girls in mathematics as shown on Fig. 1.

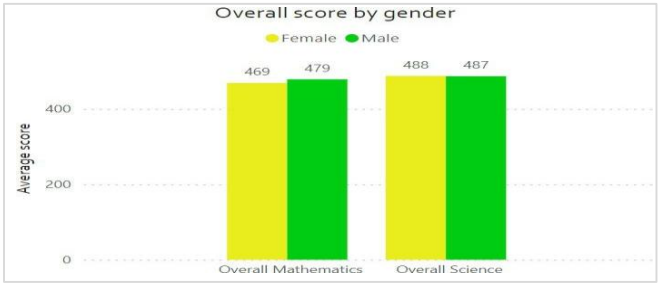

Figure 1. Overall mathematics and science performance of French women and men 2022

The PISA data also reveal performance gaps within France based on socio-economic status, with advantaged students outperforming disadvantaged students by a significant margin in mathematics.

The overall result shows a particularly striking decline in mathematics, following a period of relative stability (OECD, 2023). Indeed, the proportion of students scoring below proficiency levels (Level 2) increased significantly compared to 2012 in all three subjects, indicating a concerning trend in academic achievement. First of all, as opposed to the science score gap, the 2022 score regarding mathematics shows a gap between French female (average score: 469) and male (average score: 479). Secondly, students in France reported improvements in their sense of belonging at school but a decline in overall satisfaction with life, reflecting broader trends seen in many countries. The PISA study estimated parameters using data from all students as described in the PISA 2022 Technical report. It also shows how standardized Warm Likelihood Estimates (WLE) correlate with index values. The WLEs were normalized for the new scale indices so that the standard deviation was one and the mean of the index value for the OECD student population was zero (OECD, 2023). Based on these several PISA measures reflecting indices, the overall stress management regarding mathematics specifically was determined as shown in Fig. 2. For instance, the mathematics anxiety index was created based on the student's answers about how much they "strongly agreed", "agreed", "disagreed" or "strongly disagreed" with six statements about their feelings when studying mathematics such as "I get very tense when I have to do mathematics homework". When this indicator has positive values, it indicates that students in this country were more anxious about mathematics than students in any other OECD country (OECD, 2023).

The results show an alarming disparity over stress and anxiety management between female and male children. The most significative disparities are the average index of female anxiety regarding mathematics which is 0.43 against -0.20 for male, and the stress resistance where female reported lower resistance (-0.55) than male (0.41).

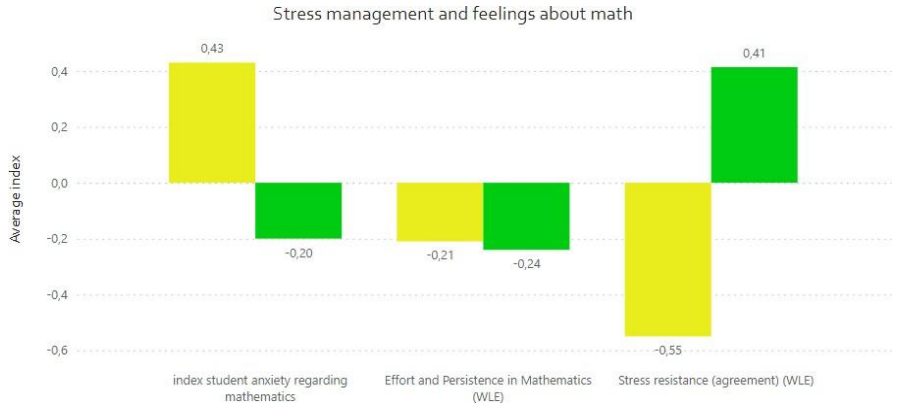

Figure 2. Key performance indicators for French regarding their feelings and stress management about mathematics by gender (OECD, 2023)

Finally, to highlight the socio-economics status that seems to impact those performance, several indicators related to family background were used. For instance, the father's and mother's occupations were linked to the international socio-economic index of occupational status (ISEI). Any parent with a higher ISEI score also has the highest occupational status (OECD, 2023). Regarding the parental education

background, the index is based on the median cumulative years of education associated with the highest level of education attained by parents. The key indicators about the parental influence have been summarized in Fig. 3.

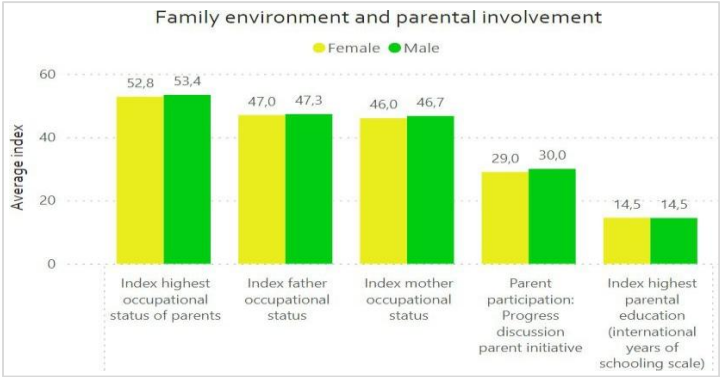

Figure 3. Family environment and parental involvement in the child's academic life by gender

The main disparity relies in parental participation and involvement in the child's academic life, with an average index of 29 for women and 30 for men. These could impact the child's performance as well as the teacher support in mathematics. Indeed, the teacher support index is derived from students' responses about the frequency of certain events in their mathematics classes, such as the teacher showing interest in every student's learning or giving extra help when needed (OECD, 2023). Positive values indicate more frequent teacher support in mathematics lessons compared to the OECD average. Nevertheless, the French average index is -0.30 for women opposed to -0.20 for men. This could be an important factor in the low enrolment of women in STEM education. Thus, the results of the PISA 2022 data analysis highlight the main factors likely to influence children's performance such as stress resistance, anxiety and, parent occupational status.

Anonymous survey participants

116 surveys were received (n = 116) with 30% identifying as male and 70% as female. Of those responding, 24.29% were grade "Seconde" (equivalent to Grade 10), 42.86% were grade "Première" (equivalent to Grade 11), and 32.86% were grade "Terminale" (equivalent to Grade 12).

Table 2. Participants profile by gender and by level.

	Grade	**Male**		**Female**		**All genders**	
French system	Equivalence	*Number*	*% Total*	*Number*	*% Total*	*Number*	*% Total*
Seconde	Grade 10	11	9,48%	37	31,90%	48	41,38%
Première	Grade 11	15	12,93%	25	21,55%	40	34,48%
Terminale	Grade 12	9	7,76%	19	16,38%	28	24,14%
	All grades	35	30,17%	81	69,83%	116	100,00%

Enrolment in STEM subjects

Most participants (96.5%) had STEM subjects in their curriculum this year. Among this sample, most cited subjects were Mathematics (93.75%), Physics-Chemistry (87.50%), and Life and Earth Sciences (83.04%). The most significant difference is in life and earth sciences, where 87.34% of women choose this subject, compared with 72.7% of men. Table 3. Summarizes of the distribution of registered participants in STEM subjects.

Table 3. Enrolment in STEM subjects by gender and level

Gender	Male								Female							
Grades	Seconde		Première		Terminale		All grades		Seconde		Première		Terminale		All grades	
Mathematics	11	100,0%	13	92,9%	7	87,5%	31	93,9%	37	100,0%	25	100,0%	12	70,6%	74	93,7%
Physics-Chemistry	11	100,0%	13	92,9%	5	62,5%	29	87,9%	36	97,3%	21	84,0%	12	70,6%	69	87,3%
Life & Earth Sciences	11	100,0%	11	78,6%	2	25,0%	24	72,7%	36	97,3%	22	88,0%	11	64,7%	69	87,3%
Numerical and Technological Sciences	0	0,0%	1	7,1%	0	0,0%	1	3,0%	0	0,0%	0	0,0%	0	0,0%	0	0,0%
Digital and Computer Sciences	11	100,0%	0	0,0%	0	0,0%	11	33,3%	37	100,0%	0	0,0%	0	0,0%	37	46,8%
Science Teaching	0	0,0%	14	100,0%	0	0,0%	14	42,4%	0	0,0%	25	100,0%	0	0,0%	25	31,6%
Engineering Science	0	0,0%	3	21,4%	0	0,0%	3	9,1%	0	0,0%	0	0,0%	0	0,0%	0	0,0%

In the French academic system, Grade 10 is the first year of high school and is a determination class that prepares students for their choice of stream in the following year. Mathematics, Physics-Chemistry, Life & Earth Sciences and Digital and Computer Sciences are therefore mandatory subjects for this level. At the end of Grade 10, students choose three specialties to follow in the general stream, but they will need to follow the mandatory subject named Science Teaching which the aim is to help students recognize the distinctive features of scientific knowledge in terms of its applications, production processes and social concerns (Ministère de l'Education, n.d.).

Therefore, the main reasons indicated for choosing STEM subjects were the requirement in their program (66.77%). Except this factor, the top three reasons are their interest in the field (64.51%), the professional opportunities (44.09%) and the higher salary expectations (14.13%).

However, some factors seem to only influence female such as parental decision or professor advice, as shown on Fig. 4. The main factor cited by women was the fact that it was a compulsory subject (43.70% of women versus 23.1% of men). On the other hand, the percentage of men who chose a STEM subject because they were interested in the field is higher (38.5%) than that of the female population (26.05%). This highlights the gap between men and women when it comes to interest in STEM.

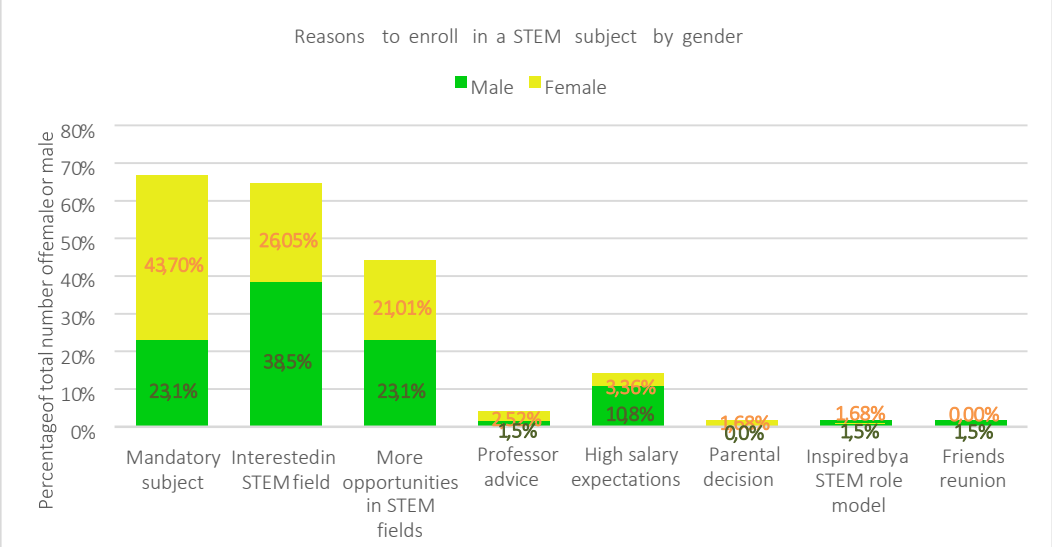

Figure 4. Reasons why participants chose a STEM subject by gender

Self-evaluation regarding STEM subjects

Regarding confidence in their abilities in STEM subjects, most participants rated themselves between 3 and 4 on a scale of 1 to 5 (1 being the lowest). However, the distribution between male and female as shown on Fig. 5.

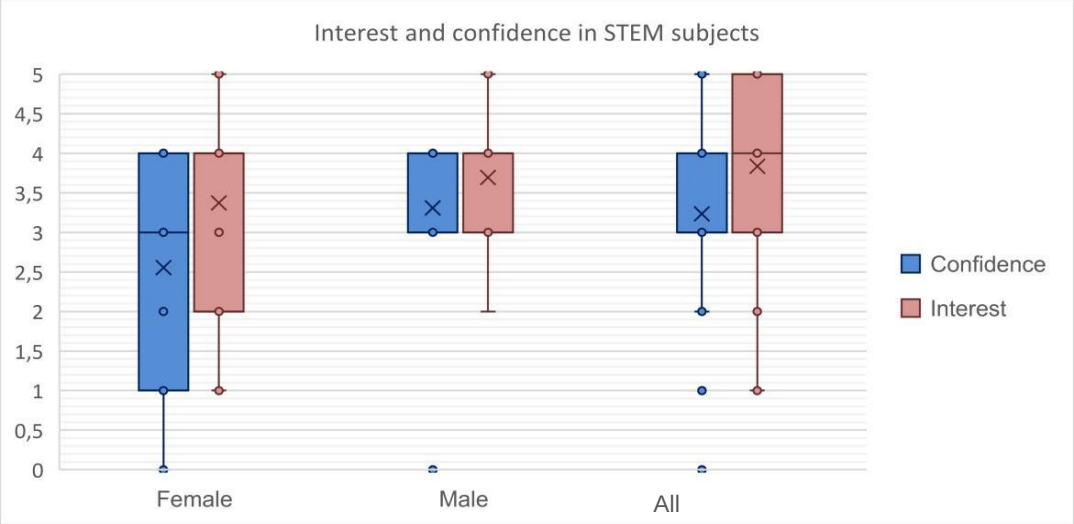

Figure 5. Participants' level of interest and confidence in STEM subjects by gender

The median confidence rating for women is lower (2.55) than for men (3.31), confirming the findings of the PISA data regarding women's confidence. In addition, the interest and confidence gaps in the female participant group are greater than in the male participant group, suggesting greater variability in interest and confidence among women as seen in reasons given by female to choose a STEM subject.
Furthermore, approximately half of the participants planned to continue their studies in STEM fields (53.45%). Table 4 summarizes the findings by level and gender.

Table 4. Participant's aspirations to continue their studies in a STEM field by gender and level

Gender		**Male**		**Female**		**All genders**	
Future in STEM fields	Grade	*Number*	*% Total*	*Number*	*% Total*	*Number*	*% Total*
Yes	Seconde (Grade 10)	9	81,82%	17	45,95%	26	54,17%
	Première (Grade 11)	8	53,33%	17	68,00%	25	62,50%
	Terminale (Grade 12)	5	55,56%	6	31,58%	11	39,29%
	All grades	**22**	**62,86%**	**40**	**49,38%**	**62**	**53,45%**
I don't know yet	Seconde (Grade 10)	1	9,09%	11	29,73%	12	25,00%
	Première (Grade 11)	5	33,33%	3	12,00%	8	20,00%
	Terminale (Grade 12)	2	22,22%	2	10,53%	4	14,29%
	All grades	**8**	**22,86%**	**16**	**19,75%**	**24**	**20,69%**
No	Seconde (Grade 10)	1	9,09%	9	24,32%	26	54,17%
	Première (Grade 11)	1	6,67%	5	20,00%	26	65,00%
	Terminale (Grade 12)	1	11,11%	9	47,37%	10	35,71%
	All grades	**3**	**8,57%**	**23**	**28,40%**	**26**	**22,41%**

Only 5.87% of the male participants are sure not to continue their studies in STEM fields as opposed to 28.40% for the female participants. Among these female students, 48.26% rated their confidence in STEM subject at 1 (lowest). However, the proportion of women and men who have considered dropping out of STEM disciplines at least once is close (60% of the male population against 72.84% of the female population). Fig. 6. Underlines the reasons.

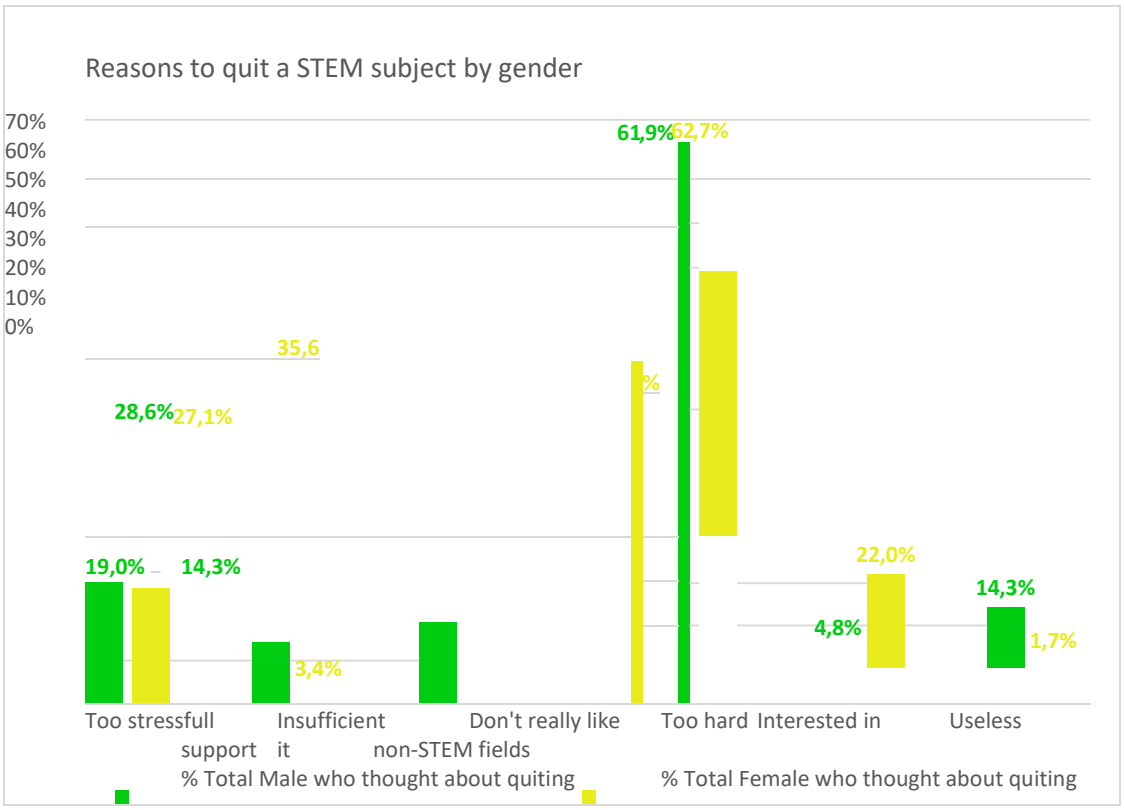

Figure 6. Participants' reasons to drop out STEM subjects from their syllabus by gender

Parental influence

A significant proportion of participants (57.45%) indicated that their parents had studied or worked in a scientific field. Among these participants, 45.05% felt that their parents' professional experience had or may have influenced their career choices to some extent. However, no significant correlation was found between students' gender or confidence in STEM subjects and parental influence.

Conclusion

The study provides a detailed examination of gender disparities in STEM education among French high school students, shedding light on the factors influencing students' interest, confidence, and enrolment in STEM subjects. We have identified key challenges and opportunities for promoting gender equality in STEM fields.

While the study contributes to the current understanding of gender disparities in STEM education, it is not without limitations. The sample size of our survey could be extended, which may improve the

generalizability of our findings. Additionally, the survey relied on self-reported data, which may be subject to biases and inaccuracies.

Despite these limitations, the study offers valuable insights for policymakers, educators, and researchers. The implementation of targeted interventions to promote gender equality in STEM education, such as mentorship programs, career guidance, and awareness campaigns are recommended. Schools should also focus on creating a supportive and inclusive environment for all students, regardless of gender. Furthermore, further research to explore the intersectionality of gender with other factors, such as socio-economic status and ethnicity, to gain a more nuanced understanding of gender disparities in STEM education could be conducted. For instance, the difficulties associated with distance learning during COVID-related school closures which may also have an impact on students' attitudes to STEM, should be further evaluated. Addressing these problems could contribute to a fairer, more inclusive STEM education system that benefits all students.

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8b. Communication for Sustainability

Full Papers

Submission ID: 174

Fostering Sustainability through Effective Communication: Perspectives from Higher Education in Cape Verde

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Abstract

Higher Education Institutions (HEIs) have a central role in communicating sustainability within and beyond their campuses. However, there is still a lack of effective involvement in "communication for sustainability" at the Higher Education level. While sustainability has recently become a pivotal point in global discourses, its integration with effective communication pathways still reveals a notable gap. This study aims to explore the existing communication models and their potential adaptation for sustainability communication plans within HEIs. A diagnosis approach was carried out through a documentary analysis of 6 existing communication models (both traditional and HEI-specific sustainability communication models) followed by a content analysis. The results show some similarities between the existing communication plans, which encompass the objectives of communication, target audiences, and types of messages or actions intended for these audiences. However, certain models, especially those formulated for communication outside the scope of HEIs, illustrate greater structural clarity and are more comprehensible to the associated community, thereby enhancing the facility of evaluation in the future. Therefore, the plan for sustainability communication at HEIs can benefit from adopting these more structured and comprehensible models, leading to more effective engagement and ensuring alignment with their intended audience objectives.

Introduction

Institutions are increasingly concerned with communication activities, recognizing them as essential for their existence and survival (Fielding, 2006). Communication in institutions should be as effective as possible, utilizing a wide range of communication activities and ensuring a good flow both vertically and across sectors. They also need communication lines with other institutions, suppliers, and customers, and networks. On the other hand, issues related to sustainability have been increasingly on the global agenda, with the need for cooperation between civil society organizations, and the political, economic, and social spheres. Building sustainability involves changing people's values and habits, and requires communication to build and disseminate a new vision of the world. The success of communication for sustainability depends on the ability to generate meanings capable of changing people's relationships with the world around them. In this context, HEIs have increasingly been considered key players in achieving sustainable development through their power to transform society (Kunsch, 2013). There is a notable increase in the interest of HEIs at a global level in implementing sustainable development by training professionals who are capable of implementing sustainability strategies and practices. In other words, HEIs are highlighted

not only for being critical in the enhancement and promotion of sustainability but also as a "transformative platform" concerning sustainable development goals through communication (Lopez *et al.*, 2018). They play a fundamental role in communication for sustainability, promoting sustainable practices, and raising awareness among both the academic community and the public about the urgency of sustainability. Through wellplanned communication approaches and strategies, they participate actively in educating, raising awareness, and instilling a feeling of environmental responsibility in their members and the broader community (Dade & Hassenzahl, 2013). However, there are still some measures that need to be improved, in particular in the communication sphere, so that topics related to sustainability are passed on by HEIs and can be understood by their recipients (Kunsch, 2013 & Lira and Martins, 2021). There is a need to delve into sustainability-focused studies in HEIs which consider communication approaches, to shape knowledge, skills, and mentality, as fundamental elements of sustainability literacy (Décamps *et al.*, 2017). This study aims to explore the existing communication models (both traditional and HEI-specific sustainability communication models) and their potential adaptation for sustainability communication plans within HEIs. The paper is built up as follows. Section two situates the study concerning the previous research on communication for sustainability, focusing on the higher education level. Section three describes the paper's methodological approach to collecting the sample plans and content analysis. Results are presented in Section four and discussed further in the same section. The study is concluded in Section five by highlighting the future steps to be taken in the study.

Theoretical Context of Communication for Sustainability in HEIs

When discussing sustainability and communication, it is essential to pay attention to the different ways in which the term can be used: Communication for Sustainability (CoS), Communication about Sustainability (CoS) and Communication for Sustainability (CoS). Both are used to refer to the subject but with somewhat different meanings.

Apart from a transformative directedness towards achieving sustainable development, communication on sustainability can occur in three more refined modes that can be analytically distinguished: Whilst communication for sustainability (Communication for Sustainability - CfS) has the main objective of facilitating societal transformation towards the normative goals of sustainable development, other perspectives of communication focus on sharing concepts and frames in the context of sustainable development (Communication about Sustainability - CaS), or transferring information from a sender to a receiver to bring a certain motivation across (Communication of Sustainability, CoS) (Godemann & Michelsen, 2011; Newig, 2011; Newig *et al.*, 2013 and Fischer *et al.*, 2016).

However, there needs to be a connection and coherence between them. It should be noted that this study will focus on communication for sustainability. According to the author, this dimension "does not stop at the transmission of informative content, but is concerned with motivations, changes, and initiatives for sustainable evolution, exerting a much greater influence, enhancing change itself (Ribeiro, 2020, p.29). Oriented towards the capacity for change and transformation, communication for sustainability aims to provide information and promote the increase of information and issues related to sustainability. It aims to help society move towards the normative goals of sustainable development. Communication for sustainability can, to a certain extent, neglect or even minimize sustainable development, because hardly anyone is actually against sustainability (Fischer, *et al.*, 2016). According to Weder (2023), the aforementioned constructive transformation that occurs in this type of communication includes the

critical and reflective perspective on communication that includes processes of problem definition (problematization), moral evaluation and questioning plus the sum of individual and group behaviors, context, and culture. It shapes and guides the conduct, and structure of institutional discourse. Communication in this case can result in the formation of new behavior patterns, the results of meaning-making processes, and participatory forms of communication, which happens in this type of communication, achieved through conversation, negotiation processes, and dialogue.

In the context of promoting sustainability in their sectors or at a broader level, institutions must take the following elements into account (The Brazilian Business Council for Sustainable Development - CEBDS, 2022): (one) careful observation before taking action; (two) putting themselves in the shoes of the listener, because what is transmitted is not always perceived correctly or in accordance with the communication goals; (three) including the different audiences that receive the communication, in order to have a greater reach of the communication; (four) adopting different types of language to transmit the messages, which will make it perceived by a greater number of people; (five) use different means of communication for different types of people, such as the web, radio, social media, community leaders, different events, social dynamics, stakeholder meetings, among others; (six) create attractive communication materials; (seven) try different approaches, such as telling stories, using good humor, showing motivating examples, with the aim of capturing people's attention; (eight) distinguish between key messages that multiply and those that only serve your company. Spread those that multiply, thus stimulating change; and (nine) communication styles should be positive and developed according to the diverse cultural contexts and contexts of the markets and communities where companies are operating.

The Brazilian Business Council for Sustainable Development (CEBDS, 2022) also presents a set of means of communication that can be adopted within the scope of communication with the different stakeholders: sustainability reports, internal and external magazines and newspapers, newsletters, websites, stakeholder dialogue programs, training and capacity building, visitation programs, press office, booklets and leaflets on socio-environmental responsibility, advertising and publicity, events, social media, and social networks.

Regarding the means of communication, Mazo & Macpherson (2017) also present some of the means by which sustainability initiatives can be communicated at HEIs, including printed materials (posters, brochures, cards, images, bookmarks, magazines, and journals); Social networks (Facebook, Twitter, Linkedin, Snapchat, etc.); Internet sites (institutional websites for sharing information about sustainable initiatives at HEIs) and in person(participation in events attended by sustainability stakeholders). Other means of communicating sustainability are presented in Cotton's (2011) study, including electronic and printed newsletters, websites, articles, seminars, lectures, and conferences. Assuming that the public of HEIs is broad and diverse, all the means of communication presented indicate that the sustainability of HEIs should cover a wide range of means of dissemination. This is because each medium is used in isolation or combination, to reach a considerable number of audiences.

The communication models could be divided based on the following categories in terms of their adaptability for HEIs:

- **Traditional communication models:** There are numerous existing communication plan models, some of which do not emphasize sustainability, while others are focused on sustainability but are not tailored for HEIs. Despite this, these models possess the potential to be adapted for sustainability

communication within HEIs. Concerning traditional communication plans, these are those that do not necessarily refer to sustainability, or do not have sustainability as their main focus, but rather organizations and the market as a whole.

- **Specific models for sustainability in HEIs:** Regarding the existing communication plans for sustainability in HEIs, these models specifically present steps or actions taken by HEIs regarding sustainable practices and how to be communicated through their campus community or beyond. As an example, University of East Anglia Model (2018) presents a set of steps that must be taken into account for the institution to communicate sustainability actions. Another example is Mazzo and Macpherson (2017) proposal on a strategic communication model for sustainable initiatives in HEIs, based on the results of a survey and teaching insights.

Methodology

The methodology of the study is shown in Figure 1. In the initial phase, a diagnostic approach was undertaken to identify existing communication plans that could be adapted for sustainability in HEIs. This step involved selecting two (2) traditional communication models and two (2) non-HEI sustainability communication models for content analysis: Kunsch Model (2003), Kotler and Keller Model (2006), Castro Model (2007) and the Baynast *et al.* Model (2018). The last two (2) models were specifically focused on sustainability but not within the context of HEIs. Additionally, two dedicated communication plans for sustainability in HEIs were identified and included in the study: University of East Anglia (2018) Model and Mazo e Macpherson Model (2017).

The second phase involved a content analysis of the identified communication plans. This analysis was divided into two parts: the first analysis explores how traditional models (non-sustainability or sustainability-focused but non-HEIs) could be adapted for sustainability in the context of HEIs. The complimentary analysis explains the main features of two (2) dedicated HEI sustainability communication plans to understand how HEIs' plans for sustainability communication function.

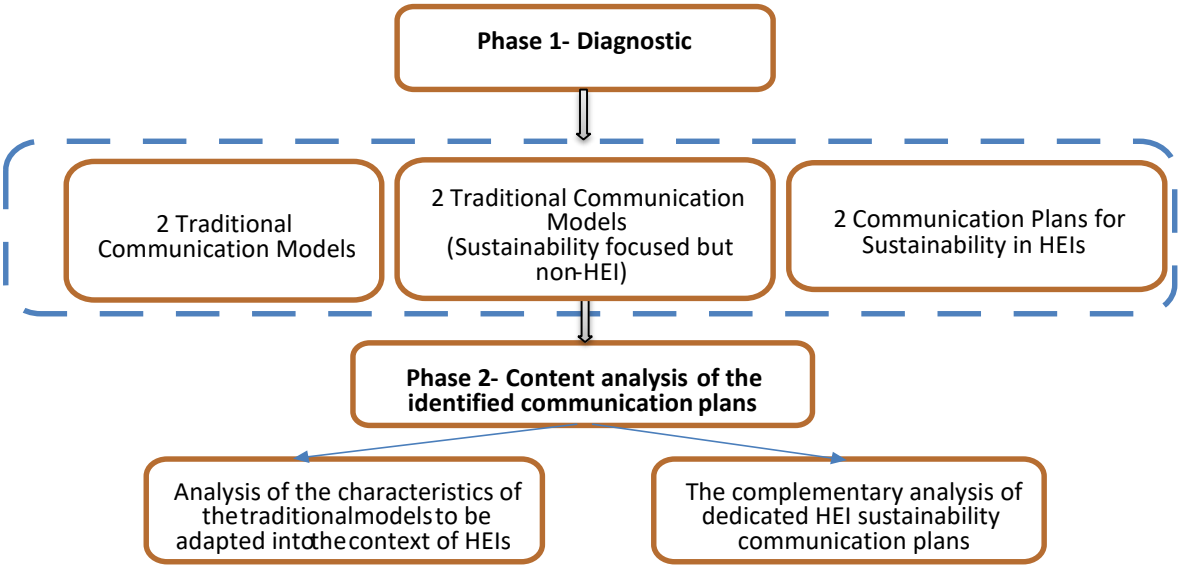

Figure 1. Methodology of the study

Results and Discussion

As referenced in the literature review, a total of 6 traditional and sustainability-focused communication models in existing HEIs were selected for content analysis. These results and remarkable points in each model are as follows:

i) Traditional communication models

- Kunsch`s model (2003)

The Kunsch (2003) communication model comprises three phases, which are broken down into twelve detailed steps (Figure 2). The content analysis of the model shows that the first phase, 'research, and construction of the strategic diagnosis of the organization', involves identifying the situational reality, collecting information, analyzing data to construct the diagnosis, and identifying the involved public (which could be an adoptable point in HEIs, since in the institutions faced with different target groups, from teachers to administrative staff, students, and even society). The second phase, 'strategic planning of organizational communication', includes determining objectives and goals, adopting strategies, forecasting alternative forms of action, establishing necessary actions, and defining the resources to be allocated. The third phase, known as 'strategic management of organizational communication', encompasses the establishment of control techniques, the implementation of the planning, and the evaluation of results. This phase is crucial for adaptation in HEIs as it can create a closed loop of sustainability communication. By continuously evaluating results and establishing continuous improvement measures within the institution, they can enhance their sustainability communication effectively and keep it updated.

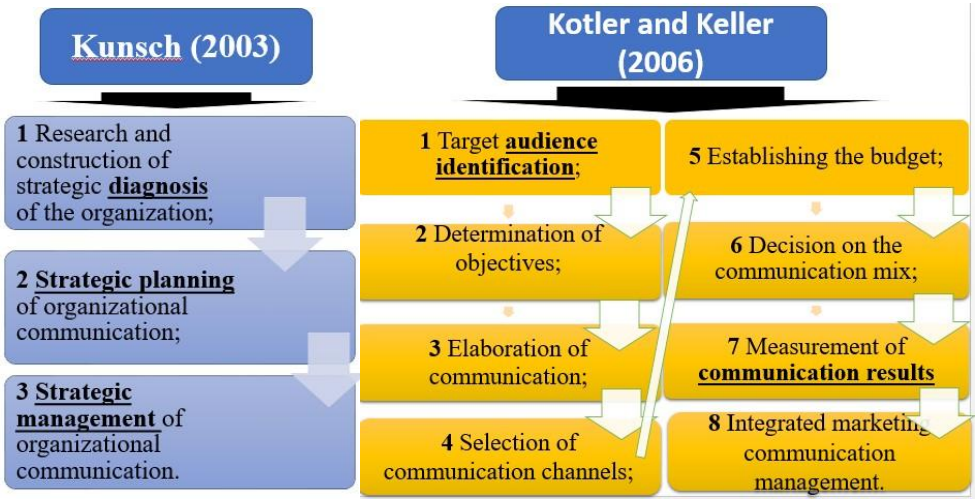

Figure 2. Content analysis of the traditional communication models (Non-sustainability focused and non-HEI)
Source: adapted from Kunsch (2003) and Kotler and Keller (2006)

- Kotler & Keller model (2006)

The authors present the steps that, in their view, should make up a communication plan (figure 2). First, a diagnosis is made, consisting of identifying the target audience, because based on the information about

the audience, namely who they are, it is possible to determine the goals of the plan, the communication goals, and the choice of communication channels that are suitable for them. In HEIs, the same step could be embedded for effective and targeted communication according to the type of target audience and their needs. The next step is to establish the budget, which is necessary given the costs of implementing the plan. The decision on the communication mix indicates which forms of communication the institutions should adopt (advertising, public relations, social media, direct marketing, among others), all can be integrated into the HEIs' sustainability communication plan, taking into account the type of audience and communication goals previously defined. The final steps include measuring communication results and managing integrated marketing communication, which are essential for knowing the level of reach and acceptance of the strategies adopted in the plan (Kotler and Keller, 2006).

ii) Non-HEIs sustainability communication models

- Castro`s model (2007)

According to Castro (2007), the communication plan is made up of at least (eight) 8 stages (Figure 3), helping institutions to achieve their communication goals based on their audiences. In the first stage, the situation is analyzed to gather information about the market and also the communication situation. This is followed by the definition of goals and positioning, selection of the target audience, choice of message, and choice of communication channels. All these stages are worked out according to the information gathered in the situation analysis, bearing in mind that it should provide detailed and indepth information about the public and the best means of reaching them effectively. As mentioned in

Kotler & Keller's (2006) model, they follow almost similar steps where the main focus stands on the audience and the best way to reach them. The next step is to determine the budget, which is also an important step given that organizations must make a rational check in terms of the expenses the plan will entail. The model ends with the execution of the plan and the evaluation of results. Evaluating the results allows the organization to check whether the initial goals have been achieved and the areas for further improvement. As also shown in Kotler & Keller's (2006) model, these are important steps that can be adapted in the context of HEIs to achieve the goals of communication for sustainability. Although not all the steps can be adopted, some can be taken advantage of, namely the diagnosis, selection of audiences, and choice of channels, which end up being included in all the plans presented.

- The Baynast *et al.,* model (2018)

Similarly, Baynast *et al.* (2018) present the steps that they consider to be important for a communication plan (Figure 3), although it is very much geared towards the marketing sphere: they begin by diagnosing the situation of the external and internal environment, to have input for preparing the SWOT analysis, through a synthesis of the information collected in the diagnosis. They then proceed to establish the main strategic guidelines that should guide an organization's strategic and operational plan. This information at the HEI level enables numerous gains, bearing in mind that the SWOT analysis, for example, presents the main strengths and weaknesses of the institutions internally and externally clearly and concisely, which makes it possible to align the communication proposal in such a way as to maintain the strengths and improve in terms of the weaknesses. The critical success factors indicate the greatest allies in the success of the institutions, e.g. quality of human resources. The plan's goals are essential to the plan's success; they must be hierarchical, consistent, measurable, time-bound, and challenging. In terms of the

strategic marketing options, this study needs to address the main communication targets, or what we want to achieve. The maneuver plan and the marketing mix indicate the priority actions and decisions within the plan, taking into account limited resources. Finally, in the action plan, contingency plan, and budget phases, the choice of actions is dedicated to establishing the activities needed to implement the plan, as well as its budget.

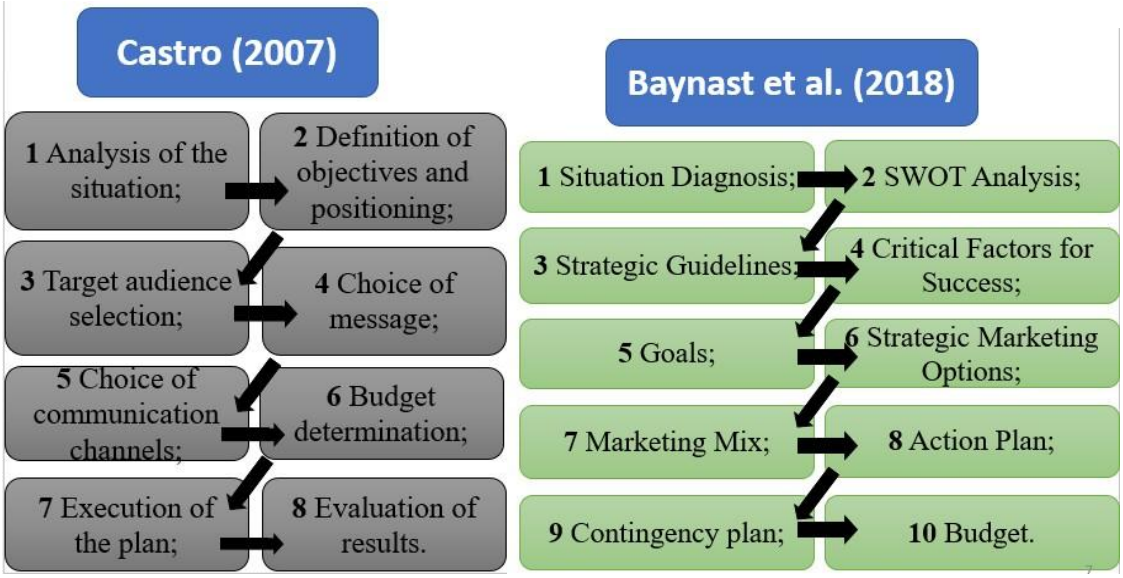

Figure 3. Results of the communication model (sustainability-focused, but non-HEIs)
Source: adapted from Castro (2007) and Baynast *et al.* (2018)

However, there are still relatively few communication plans that address how communication for sustainability should be developed, particularly in HEIs. This indicates that the specific plans for sustainability at HEIs should be analyzed, as they will have more targeted elements for having a communication plan that is consistent with communication for sustainability

iii) Specific models for communicating sustainability in HEIs

- University of East Anglia (2018)

Regarding existing sustainability communication plans at the HEIs level, the model of the University of East Anglia (2018) (Figure 4) consists of seven (7) stages, providing information on the institution's sustainability communication practices. As discussed in the Baynast *et al.* (2018) plan, every effective sustainability communication plan requires a diagnosis before adopting communication strategies for the public. Therefore, the plan initiates with an introduction on the background and overview, offering insights into gaps in the engagement of staff and students in meeting environmental management objectives. The subsequent stage involves a review of the institution's extensive (by size) and diverse stakeholders, aiming to ensure satisfaction for as many of them as possible. The key messages then should be selected according to the priority groups made up of i) executive Team, ii) current staff and students, iii) potential and future audiences, and iv) Partner organizations. It should be noted that this stage also presents the target audiences for the communication. The key messages proceed and are developed differently for internal and external audiences. The University of East Anglia has developed its brand or

identity: 'UEA (Univerity of of East Anglia) Sustainable Ways', @SustainableUEA online, to convey the University's commitment to sustainability and to facilitate connections across networks and programs. The communication methods stage presents the tools and means of communication, the type of message, the frequency of communication, and the stakeholders. The penultimate step, responsibility, presents those responsible for implementing and monitoring the plan. The last stage of the plan is useful links and presents links that could be accessed for more information about the institution's sustainability activities and practices.

- Mazo and Macpherson model (2017)

Propose a strategic communication model for sustainable initiatives in HEIs (Figure 4), which is based on a set of strategic questions aimed at focusing on the university's communication approaches and a project management framework that guides strategies and tactics along a range, from more generalized and abstract considerations to more specific and direct actions. The model consists of four straightforward steps: i) if the HEI has a sustainability plan, ii) if the HEI identifies effective communication strategies for sharing sustainability information at its institution, ii) if the HEI defines essential criteria for inclusion in its strategic communication plan for sustainability, and iv) if they prioritize strategic communication approaches in sequence.

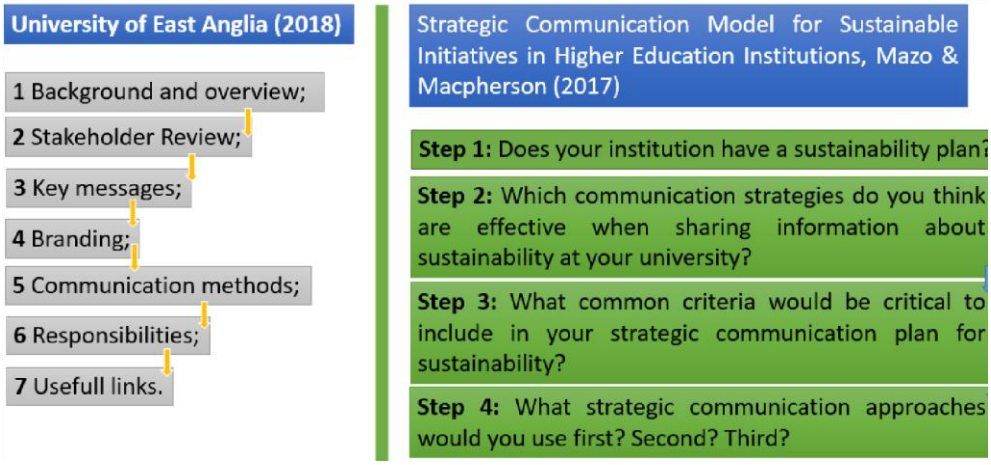

Figure 4. Content analysis of Sustainability Communication Plan in HEIs
Source: adapted from University of East Anglia (2018) and Mazo & Macpherson (2017)

By reviewing the models, it is evident that there are both similarities and differences among them. One notable similarity across these models is their initial focus on gathering information about the “current state of institutions”. This data serves as a foundation for implementing the plan, informing proposals for new directions. Additionally, all plans feature objectives, crucial for clarifying the desired outcomes of the plan. Addressing the public is also a common feature in the plans, recognizing them as primary recipients of communication messages. Finally, the content analysis shows that effective communication strategies involve targeted messaging tailored to specific audiences, utilizing diverse channels for dissemination. However, there are some differences between traditional communication plans and those focusing on sustainability. For instance, Kunsch's (2003) model places a greater emphasis on organizational or institutional-level communication strategies compared to others.

The models by Baynast *et al.* (2018) and Kotler and Keller (2006) are more focused on communication with a marketing focus and marketing goals. The communication plans of the University of East Anglia and Mazo & Macpherson (2017) are suitable for communicating sustainability in HEIs, by presenting steps particularly associated with communicating sustainability at the HEIs level. These steps were structured following research carried out in universities in three countries (Canada, Ecuador, and Ukraine), where Mazo & Macpherson (2017) propose a model for environmental and sustainability communication that can be applied universally and at the same time provide customized strategic guidelines for HEIs. As a summary, those models that particularly associated with communication beyond HEIs, demonstrate greater structural clarity and are more easily understood by the associated community. This clear structure can simplify future evaluation steps by providing clear criteria that facilitate systematic assessment and continuous improvement. Incorporating these structured and easily understandable models into sustainability communication plans at HEIs can improve engagement and ensure that the communication aligns effectively with audience objectives. It is believed that combining the various types of plans presented above would be advantageous for the aforementioned research, as the perspectives of organizational, marketing and sustainability plans present elements that complement each other and, as a result, help in the creation of a set of steps to achieve a sustainability communication plan at HEIs.

Conclusion

This study aims to boost communication for sustainability in HEIs. As presented throughout the document, there are certain gaps when it comes to communicating or passing on information about sustainability issues. In this sense, it is proposed to develop a communication plan for sustainability at the HEI level, consisting of a set of proposals and paths that should be adopted and that can contribute to a better understanding of the true notion of sustainability. If there are people who adopt sustainable practices without knowing they are doing so, it will show them how to improve and how they can adopt other practices, through targeted communication. This plan also allows HEIs to share their sustainable practices both inside and outside their campuses with the public. Regarding the next steps to be taken in the study, we highlight the preparation and application of the individual and focus group interviews with those associated with the administrative or managerial levels in HEIs context, as well as the development of questionnaires with students to collect their perceptions and future needs on communication for sustainability in their institutions.

Acknowledgment

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8c. Just Transitions

Abstracts

Submission ID: 125

Justice in Nature-Based Solutions: A Framework for Just Sustainable Design Practices

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Abstract

Urban planning and design practices have contributed, whether intentionally or unintentionally, to the disparity in quality of life across generations and among socially marginalized and vulnerable communities. Nature-based Solutions (NbS) have been globally adopted in policies as a key strategy for coping with climate change. However, these adoptions often overlook justice in achieving sustainable development goals. At the local scale, climate justice considers the systemic vulnerability of communities in coping with climate change-associated hazards and applies an intersectional approach of vulnerability, resilience, and sustainability to understand community resilience (Cheng 2022). The concept of Climate Justicescape has been developed as a framework for spatial analyses of social-ecological-technological systems and distributive justice to vulnerable populations and urban resilience (Cheng 2016, 2019).

This research aims to address justice, design, and sustainable design of NbS in urban and community resilience. We propose an integrated design justice theory and practice framework with four dimensions of justice to transform society in rectifying justice systems and practices. Drawing from justice theory and urban design practice, this research proposes a framework to integrate theory and practice in addressing climate justice by embedding four areas of justice—procedural, distributive, restorative, and generational justice—in the co-design process with communities on solutions related to SDG 11+Target 11.3. The literature review and case studies from design education and practices suggest an interactive co-design procedure. The research proposes a climate justice design framework outlining a design process that includes meaningful engagement with communities and governance with justice principles for an inclusive sustainable development process and outcome. This framework is crucial to achieving justice in sustainable development and ensuring that further investment in sustainable design practices does not perpetuate persistent systemic injustice.

Our framework, with illustrations of NbS design justice practice, is intended to be applied at various scales and allow communities to customize and contextualize in the local context. The implementation of NbS and sustainable design with justice as core guiding principles and values will rebalance power and priorities in the decision-making process to address justice goals in every community.

Submission ID: 189

Renewable Energy and Environmental Justice Nexus in Africa: A Systematic Literature Review

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Abstract

Historically, the world has gone through various phases of energy transitions such as the transition from whale oil to kerosene and from wood to coal (Carley and Konisky, 2020). The present-day renewable energy (RE) transition (from fossil fuel to RE) is coming against the backdrop of chilling evidence linking the climate crisis to fossil fuel usage (Levenda, Behrsin, Disano, 2021). The whole value chain of the fossil fuel industry (and the resultant climate change) has been linked to disproportionate impacts on the poor sections of society (Outka, 2012). The most recent (sixth) synthesis report from the United Nations Intergovernmental Panel on Climate Change makes it abundantly clear that averting the effects of climate change will require a stop to the development of new fossil fuels, phasing out the use of existing fossil fuels and bold shift to RE (Centre for Biological Diversity, 2023). In light of this, the number of RE projects being implemented in Africa has increased in recent years and is predicted to continue to rise as we move closer to 2050. Studies have shown that there will be winners and losers in transitions (Outka, 2012; Carley & Konisky, 2020), therefore interrogation of RE transition through the lens of environmental justice (EJ) is paramount. This systematic literature review, utilising the PRISMA approach examined peer-reviewed journal articles on RE transition policies, processes, and programs from the perspective of EJ at the community level in Africa. The societal benefits of RE projects implemented in Africa have not been studied thoroughly (Ikejemba & Schuur, 2020), worse still in the context of EJ. A few studies have shown mixed benefits of RE projects in communities.

***Keywords**: Africa, environmental justice, renewable energy, just transition*

Submission ID: 196

The Energy-Poverty Nexus and Just Transitions in the Arctic

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Abstract

People living in and near the Arctic, in communities across Alaska, Canada, Norway and Russia have to contend with multiple infrastructural challenges. The harsh climate, remoteness and sparseness of the region is a cause and a compounding factor to the vulnerability of infrastructure. In this backdrop, energy transitions i.e., the shift from traditional sources of energy to fossil-based and more recently, renewable energy infrastructure holds a critical position of influence in causing generative or extractive shifts to the quality of life in Arctic communities. This interaction of energy systems with systemic poverty and its potential to either enable or impede sustainable development pathways is termed as the energy-poverty nexus.

The study captures several examples form the Arctic geography, illustrating the diverse ways in which energy transitions are creating conditions for enhancing sustainability, creating landscapes of uneven burdens and benefits, or forcing trade-offs that holdback the pursuit of safe and culturally generative sustainability. Deconstructing specific examples of the energy-poverty nexus using a sociotechnical systems approach, this study investigates the phenomenon from three intersecting perspectives – the household and community level interactions, energy production and its political economy, and the role of institutions. The analysis two aspects of energy transitions that are critical to the formation of the energy-poverty nexus. First is the increasing dependence of critical infrastructure and services, e.g., transport, water, municipal services on less diverse and increasingly sophisticated energy infrastructure. The expertise thresholds for financial, technical and governing functions of the energy infrastructure lowers opportunities for localized innovation to address the nexus. Secondly, the socio-cultural shifts and economic burdens brought about in the lifestyles and social practices affect the capabilities of households and communities to cope with change. In the case of Indigenous peoples of the Arctic, such changes extend their contestation between traditional and colonially imposed ways of living, while for settler communities it is cause for burdens to their constructed ways of living.

The analysis identifies points of intervention including accelerating the energy transitions in ways that costs of coping are minimized, complementary interventions in other infrastructure domains to lower their dependency on energy systems, and investing in social, cultural and economic interventions to enhance quality of life parameters directed at households and communities. These findings have important lessons for pursuing multiple SDGs in Arctic geographies, both independently and as interconnected goals. This predominantly includes poverty (SDG1, Targets 1.4,1.5), affordable and clean energy (SDG 7, Targets 7.1 – 7.3), climate action (SDG 13, Targets 13.1, 13.b), peace and justice strong institutions (SDG 16, Target 16.6, 16.b), among other SDGs. The findings are also relevant to other geographies with harsh climates and difficult terrains like the Himalayan region, broadening the scope of knowledge exchange for sustainable development.

Track 9 Governance and Institutional Frameworks

9a. Peace and Sustainable Development

Abstracts

Submission ID: 13

The Futures of Peace and International Law

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Abstract

Maintaining peace and stability in a period of unparalleled global challenges requires the sustainability of the core tenets of international law. This paper examines the application of international law especially against potential threats to global peace emanating from geo-political conflicts, territorial disputes and resource scarcity or rivalry. It will examine the current trends in the application and interpretation of international law from international courts and tribunal decisions, publicists and public opinions. The trends in international law through a shared historical lens will be analyzed from its conception, in particular the intentions and objectives as manifested in texts and context of the treaties and the preambles of key legal instruments such as the United Nations Charter. Drawing upon futures studies methodology, this paper aims to construct plausible scenarios for the future of international law. These scenarios include the preferred future, envisioning a world where collaboration among nations flourishes from a democratized and reformed structure of international law; the unwanted future, characterized by the neglect of international legal norms and escalating conflicts; business as usual, depicting a continuation of current trends with slow changes; and the outlier, representing unforeseen disruptions or paradigm shifts in the international community. In the present moment in the international law history, with the most contested conflict in the century being brought to the International Court of Justice, it offers a unique opportunity to influence international law and state practice towards a more inclusive and equitable framework, contributing to the maintenance of global peace and stability. By exploring these future scenarios, policymakers, legal scholars, and stakeholders will gain valuable insights into the challenges and opportunities inherent in shaping the future of international law.

Submission ID: 214

Seven incidents within a fortnight in Nepal: Is violence against healthcare professionals curbed by tougher laws?

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Abstract

In September 2023, a surge of violence against healthcare professionals occurred in Nepal within a two-week span, despite recent legal amendments aimed at curbing such incidents. This manuscript explores whether stricter legislation effectively deters these acts. The violence is rooted in Nepal's healthcare system's inadequacies, leading to overcrowded and understaffed hospitals, patient frustration, and healthcare professional burnout. Misinformation and rumors, particularly in rural areas, can trigger outbreaks of violence, exacerbated by media sensationalism. The lack of legal consequences for attackers is a significant factor. Perpetrators often go unpunished, emboldening others to resort to violence when dissatisfied with medical services. Political affiliations and third-party involvement for financial gain are common. The psychological toll on healthcare workers is profound, resulting in burnout, depression, and post-traumatic stress disorder, contributing to a significant brain drain of doctors from Nepal. The paper underscores the importance of enforcing existing laws to create a safe workplace and making the malpractice complaint process accessible to the public to deter resorting to violence.

Full Papers

Submission ID: 170

Examining the Role of Nepalese Social Entrepreneurs in Advancing Sustainable Development and Circular Economy Practices

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Abstract

Despite fifty years of development initiatives, Nepal continues to face significant societal challenges, with vulnerable populations impacted by both governmental and international projects. Environmental issues such as pollution, inadequate waste disposal, biodiversity loss, deforestation, and soil degradation are on the rise. Persistent problems like poverty, limited access to healthcare and education, gender disparities, infrastructural deficits, unemployment, cultural biases, and reliance on external aid remain. Traditional educational institutions prioritise market-oriented values over environmental awareness, compassion, and empathy.

This research investigates the pivotal role of Nepalese social entrepreneurs in advancing sustainable development and fostering circular economy practices to address these issues. Through qualitative analysis of interviews and case studies, it explores the impacts of social entrepreneurship on Nepal's sustainable development landscape. Social entrepreneurs in Nepal are leading the transition to a sustainable lifestyle, using their talents and resources to promote justice, equality, and humanity. They are innovating education by integrating nature and sustainability into learning. Despite facing social stigma and community resistance, social entrepreneurs empower marginalised groups, including the disabled and trafficked victims, turning them into agents of change. Many have made significant personal sacrifices to contribute meaningfully to society, embodying solidarity and commitment to achieving social goals amidst various challenges.

Introduction

Social entrepreneurship has evolved significantly since its early conceptualization in the early 1990s, with a notable increase in scholarly interest from 2010 onwards. Initially, SE was defined, and its boundaries established, but subsequent research has delved deeper, employing theoretical frameworks such as institutional theory and social capital theory (Battilana & Lee, 2014; Estrin *et al.*, 2013). Social entrepreneurs are often portrayed as agents of change, addressing unjust and unsustainable systems and transforming them into sustainable models (Martin & Osberg, 2015). This conceptualization highlights the role of social enterprises in tackling pressing economic and environmental challenges, a role that has gained increasing recognition (Dwivedi & Weerawardena, 2018; Hota *et al.*, 2020). Unlike traditional commercial entrepreneurship, SE emphasises social value creation alongside economic objectives, highlighting a dual focus on social and economic goals (Cherrier *et al.*, 2018; Zahra *et al.*, 2009).

According to the World Economic Forum (2023), social enterprises also play a crucial role in developing and expanding the circular economy, providing social and environmental benefits worldwide.

The economic impact of SE is significant. A 2015 study of over a thousand social enterprises in nine OECD countries revealed that these enterprises generated over EUR 6 billion in revenues and created approximately 6 million jobs, including around half a million positions for individuals from vulnerable groups (OECD, 2017). This demonstrates SE's potential not only as a social force but also as a substantial economic driver. Scholars argue that entrepreneurs are agents of change who create social and material value, thus positioning entrepreneurship as inherently social (Johannisson, 2008; Steyaert & Hjorth, 2006). However, debate persists as to whether SE can be considered a more compassionate form of business entrepreneurship, given its dual focus on profit and social impact (Austin *et al.*, 2006; Spear, 2006).

SE blurs traditional boundaries between the public, private, and non-profit sectors, advocating for hybrid models that combine for-profit and non-profit activities (Johnson, 2000). This blending creates a compelling business model that humanises business practices and makes development processes more self-sustaining. SE is thus seen as a method for discovering, defining, and exploiting opportunities to increase social wealth, either by establishing new enterprises or reorienting existing ones (Schwab Foundation, 2014). The driving forces behind the global expansion of SE include the disparity of wealth, the evolution of corporate social responsibility, market and institutional failures, and technological innovation, all of which highlight a shared obligation towards sustainable development (Zahra *et al.*, 2008). The concept of SE is multifaceted, with its interpretation varying based on cultural, geographic, and historical contexts (De Bruin & Teasdale, 2019). Despite these variations, sustainability remains a core value across all definitions of SE (Trexler, 2008). Sustainability is often described as balancing the complex relationship between human culture and the living world, emphasising the need for a harmonious coexistence between these two systems (Hawken, 2007). However, the term "sustainability" itself is subject to diverse interpretations: ecologists see it as the maintenance of biological systems, while economists often interpret it as improving living standards. This ambiguity, however, has not prevented sustainable development from becoming a key objective for global institutions and enterprises (Kates, Parris, & Leiserowitz, 2016).

In 2015, world leaders made a historic commitment to ensure everyone's rights and well-being on a healthy, thriving planet. They did this by adopting the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs). This Agenda is a global plan to end poverty, protect the planet, and tackle inequalities. The 17 SDGs provide a practical guide to addressing the root causes of issues like violent conflict, human rights abuses, climate change, and environmental damage. These goals are based on the idea that sustainable development must include economic growth, social well-being, and environmental protection (Martin, 2014). Nepal joined the 2030 Agenda for Sustainable Development in the same year, having already made considerable progress under the Millennium Development Goals (MDGs) by reducing extreme poverty, hunger, child and maternal mortality rates, and combating diseases. Nepal has been a dedicated member state in the introduction, familiarisation, awareness, and implementation of the all-encompassing SDGs. With the inception of federalism, Nepal comprises a federal government, seven provinces, and 753 local units. Localising the SDGs at the subregional level is a major step that needs to be taken (Yadav, 2019). Achieving the SDGs requires collaboration among governments, the private sector, civil society, and citizens. In Nepal, the UN collaborates with these key groups to ensure the country's SDG commitments are realized. The UN partners with the government to

nationalise SDG targets, implement them, mobilise resources, and monitor progress towards achieving the goals by 2030. While progress is happening in various areas, overall action to achieve the Sustainable Development Goals is not advancing quickly or extensively enough (Martin, 2020).

Social entrepreneurs are considered as important implementers of SDG. Social entrepreneurs focused on education, healthcare, microfinance, and socio-economic development in rural areas has impacted millions (Bornstein and Davis, 2010). These organisations demonstrated that alleviating poverty on a massive scale is consequently, social entrepreneurship can be scaled up and used to rebuild the country by helping marginalised groups empower themselves. According to Botstein (2004), social entrepreneurs have historically addressed social issues by empowering individuals through microfinance, tackling health challenges like HIV/AIDS, and providing education and skills training. They have also promoted environmental conservation, engaged in public reconstruction projects like housing associations, run welfare programmes for the unemployed and those with substance abuse issues, and advocated for causes like fair trade and human rights. It is argued that social entrepreneurs are key drivers of sustainable development (Stenn, 2017), especially when other sectors are primarily motivated by profit. Social entrepreneurs view themselves as integral parts of a larger whole and strive to make a positive impact through sustainable activities. They bring together ideas, skills, resources, and social actions to achieve sustainable social development (Alvord, *et al.*, 2004), and they promote circular economy strategies, which are a very important tool to promote sustainable development (Schröder *et al.*, 2020). Therefore, social entrepreneurs are trying to ensure these goals are met by 2030.

This study aims to explore the role of social entrepreneurs in contributing to the SDGs, their awareness of these goals, and whether supporting the SDGs and circular economy practices was part of their original motivation. The study examines the strategies and initiatives implemented by these entrepreneurs, their impact on local communities, and their broader implications for sustainable development. Through an in-depth analysis of case studies and existing literature, this study highlights how social media contributes to reducing poverty, boosting health and well-being, bridging the gender gap, promoting quality education, and promoting a sustainable economy in Nepal.

Literature Reviews

Social entrepreneurship (SE) in Nepal is deeply rooted in its societal, economic, legal, and cultural contexts. Directly applying American and European methodologies to SE in Nepal is not feasible (Defourny & Nyssens, 2012). Therefore, it is essential to develop and discuss models that are specifically tailored to Nepal's unique context. Although social entrepreneurship began to gain traction in the business ecosystem around 2009, creating SE models adapted to Nepal’s environment remains crucial. Historically, social enterprise practices have been prevalent in Nepal. For example, the Newars established the 'Guthi' system millennia ago to maintain socio-economic stability (Shrestha, 2018). While innovation and SE are gaining popularity in South and Southeast Asia, these concepts are still in their initial stages of development. Only South Korea has enacted specific legislation supporting social enterprises (Defourny & Nyssens, 2012).

Nepal hosted its first international SE conference at King's College in June 2016, themed "Rebuilding Nepal through SE." This conference featured participants from 12 countries and included presentations from

eight national and thirty-seven international speakers, as well as 12 research papers (Gautam, 2016). In 2008, ChangeFusion Nepal was founded to foster successful social businesses by providing essential resources for creating sustainable social and economic benefits through entrepreneurship, networking, and innovation. They support social entrepreneurs with novel ideas, solutions, dedication, and a vision for social change (ChangeFusion Nepal, 2018). Since 1987, numerous fellows from Nepal have been recognised by Ashoka for their work across various fields such as journalism, environment, agriculture, handicrafts, energy, and ageing (Network Search, 2018). Despite the establishment of many social enterprises, no Ashoka Fellows from Nepal were recognised between 2008 and 2017. Furthermore, some Nepalese social entrepreneurs have been honoured by the UN for their contributions towards the Sustainable Development Goals (SDGs), and many have received national accolades, including the Surya Nepal Asha Entrepreneurship Award since 2012. Therefore, social entrepreneurship in Nepal is gaining momentum but remains under-explored (Jirel, 2020). The Constitution of Nepal supports the SDGs by ensuring inclusive social, economic, and political changes and eliminating all forms of discrimination (Government of Nepal National Planning Commission, 2017).

Sustainable development has become a prominent growth model over the past two decades (Sarvaes, 2013). The Brundtland Report was pivotal in highlighting fundamental issues and obligations related to sustainable development, including problems of people and development, food access, biodiversity, energy, trade, and urban challenges (WCED, 1987). Today, sustainable development is commonly used to assess human impact on ecosystems and resources, although approaches to achieving it vary widely (Seyfang & Smith, 2007). Despite many businesses aiming for sustainability, few have made substantial efforts. The problems humanity faces today, including climate change, terrorism, epidemics, deep cracks in world trade, and threats to biodiversity and ecosystems, often stem from those struggling to survive off of nature and globalisation (Friedman, 2009). Business and politics are unlikely to solve these issues soon, as no correct strategies exist for tackling these "new" and overly complex problems (Sarvaes, 2013). There is a need for an assessment framework to classify programmes, projects, plans, and/or policies with the potential for sustainability (Lennie & Tacchi, 2011, 2013). Sarvaes (2013) suggests countries and governments should address these multidimensional and multifaceted problems incrementally, with politically consulted baby steps, rather than attempting bold, singular actions. However, Friedman (2009) argues that addressing these problems one at a time is ineffective; instead, a systemic solution is needed for these colossal and systemic issues.

Sustainability is founded on the "triple bottom line" of economic, societal, and environmental growth, a concept introduced by Elkington (1997). This framework suggests that sustainable development involves creating value for the planet and people along with profits. It posits that economic development should not be the sole objective but should also ensure the well-being of present and future generations (Misiūnas & Balsytė, 2009). Phra Dhammapidhok, a well-known Buddhist monk and philosopher, asserts that Western scholars' views on sustainable development lack a focus on human well-being and overemphasise competition. In contrast, sustainability from a Buddhist perspective involves the ecosystem, social wealth, and "evolvability"—the capacity of individuals to transform into less selfcentred people (Payutto, 1998). The fundamental principle of sustainability is to inspire and persuade people to live harmoniously with nature without controlling or destroying it. Consequently, the current exploration of sustainability has broadened to encompass commercial, cultural, social, and ecological efficacy, aiming to preserve or improve financial, societal, and ecological well-being (Dyllick & Hockerts, 2002; McDonough & Braungart, 2002; Young & Tilley, 2006). The increasing focus

on sustainability has led to diverse business models, such as Permaculture, the social solidarity economy, and the Circles of Sustainability, which emphasise ecological, social, and economic goals (Steen, 2017). However, implementing these models often faces significant challenges, including resource limitations and varying degrees of commitment from businesses and governments (Omrane, 2013). Sustainability does not occur independently; it requires deliberate effort, practice, integration, and dissemination (Steen, 2017). Sustainability lenses (SL) can be used in business models to identify opportunities, areas for positive change, and ways to improve the well-being of businesses, communities, employees, and the environment. The Andean model "Suma Qamana," meaning "living well," is an integrated approach to grassroots sustainable development, governance, and policy (Choquehuanca, 2010). Promoted by the UN as a viable model for local development in 2009, it, along with the 'Circles of Sustainability'—a four-quadrant model encompassing ecology, economy, politics, and culture—defines and quantifies sustainability in place-based environments (Steen, 2017).

The SDGs are considered a radical and innovative approach to global development (Ghorbani, 2021). The UN claims that the SDG framework was developed through extensive consultations with governments and civil society, giving a greater voice to the poor and making it more legitimate compared to the Millennium Development Goals (United Nations Sustainable Development, 2016). They aim to address a wide range of global challenges, including poverty, inequality, health, education, and environmental sustainability. However, some view the SDGs as overly ambitious and not sufficiently actionable (Radford, 2015; Jack, 2015). Critics argue that the SDGs rely too heavily on traditional economic growth models, which may not adequately address underlying issues such as inequality and environmental degradation (Hickel, 2019). They believe the SDGs are inconsistent and challenging to quantify, implement, and monitor. Analysts suggest a potential conflict between goals promoting socio-economic development and those advocating for environmental sustainability. The goals are non-binding, with each country expected to create its own plans, yet there is uncertainty regarding the sources and amounts of financial resources required (Swain, 2018). The goals have been described as "vague, weak, or meaningless" (Holden, *et al.*, 2016, p. 214). Jason Hickel from the London School of Economics criticises the SDGs, stating that they represent a missed opportunity and are even harmful because they tie global development to a flawed economic model in need of deep structural changes (Radford, 2015).

UN Agenda 21 has also been controversial, with some viewing it as an attempt by the UN to dominate the world by controlling land, replacing free enterprise with public/private partnerships, indoctrinating children into state control over family allegiance, and significantly reducing the population (Femine, 2013). Koire (2011) argues that Agenda 21 instructs governments to control all land use and remove decision-making powers from landowners, thereby restricting individual freedoms and resources and silencing dissent. She advocates for self-sustainability and grassroots activities in every country and community. It is also suggested that developed countries focus on social and environmental policies; while developing countries prioritise economic and social policies in the short term, though environmental policies remain crucial for long-term sustainability (Swain, 2018).

In the context of social entrepreneurship, the SDGs have been grouped into four categories: addressing poverty and inequality, improving the quality of work and life, managing the environment, and managing the economy sustainably (Ridley-Duff & Wren, 2018). Each SDG has related goals that can be used to explain grouping them to show logical relationships between them.

Table 1. Social Enterprise, Sustainable Development and Fairshare Model

Group	SDGs	Description
Addressing poverty and inequality	1,2,5,10	▪ Ending poverty globally (1) ▪ Ending hunger, attaining food security and improving nutrition (2) ▪ Ending gender discrimination and empowering women and girls (5) Reducing polarity within and amongst the counties (10)
Improving the quality of work and life	3,4,8,16,17	▪ Ensuring health and well-being for all (3) ▪ Safeguarding inclusive and decent quality education (lifelong) (4) ▪ Promoting sustained, comprehensive, and viable economic development and creating dynamic employment and decent job for all (8) ▪ Access to justice through inclusive institutions (16) ▪ Revitalizing the universal partnership for sustainable development (17)
Sustaining the environment	6,7,13,14,15	▪ Assuring the availability of water and sanitation and their sustainable management (6) ▪ Making affordable, dependable, viable and renewal energy accessible (7) ▪ Acting urgently to fight global warming and its effects (13) ▪ Sustainable use and conservation the water bodies (14) ▪ Restoration and sustainable use of ecosystems (15)

Source: Adopted from Department of Economic and Social Affairs Sustainable Development (United Nations, 2016).

Constitution of Nepal supports SDGs by ensuring inclusive social, economic, and political changes and eliminating all forms of discrimination (Government of Nepal National Planning Commission, 2017). The NPC's 2017 report, 'National Review of SDGs,' details how the constitution directs new policies, plans, programs, and interventions aimed at achieving the SDGs. The government has begun integrating SDGs into national programs and planning systems. The Fourteenth Plan (2016/17–2018/19) incorporates the SDGs into periodic plans, and the budgets for 2016/17 and 2017/18 align with SDGs by including SDG coding in all programs (Clash, 2017). This research explores how social entrepreneurs are playing their part.

Methodology

The researcher employed a qualitative research methodology, focusing on the collection, organisation, and analysis of textual data. This methodology was chosen for its ability to generate new insights and theories, particularly in under-researched areas like social entrepreneurship in Nepal (Richards, 2009). Qualitative research is well-suited for exploring complex social phenomena, allowing for an in-depth understanding of participants' perspectives (Yale University, 2015). The study concentrated on social entrepreneurship (SE) and involved interviews with various stakeholders, including social entrepreneurs, impact investors, a research coordinator, and members of a political party advocating for entrepreneurship. According to Creswell (2012), "qualitative research enables an individual to tell their stories and diminishes the authority between the researcher and participant" (p. 48). Furthermore, qualitative research turns the world into a series of representations, including interviews, field notes, photographs, recordings, conversations, and memos to oneself (Denzin and Lincoln, 2011).

The researcher used in-depth interviews with twenty-eight participants to gather data due to the significant qualitative components of the study. The data was generated using proposed and evolving

methods, incorporating open and non-directive questions. The researcher employed thematic analysis to interpret the data. A qualitative approach allows for a comprehensive exploration of the experiences, strategies, and impacts of social entrepreneurs in Nepal, providing rich, detailed insights that quantitative methods might not capture. Interpretative qualitative analysis is instrumental in uncovering general information about less understood topics, considering the research design, offering preliminary answers to research questions, and laying the foundation for the study. The researcher conducted interviews with twenty-two social entrepreneurs, three impact investors, a research coordinator at a think tank, and two members of a political party promoting entrepreneurship. A total of 28 individuals participated in interviews, with the sample size determined by the principle of saturation, where new data no longer significantly contributes to understanding the research questions. This method, characterised by openended questions, allows for a comprehensive exploration of respondents' views and experiences (Bryman and Bell, 2015). The interview guide, prepared in advance, allowed flexibility to explore new insights during the conversations.

The researcher adopted a purposive sampling method, later complemented by snowball sampling. This approach involved selecting participants based on specific characteristics relevant to the study's objectives, ensuring diverse representation within the SE community. Follow-up phone interviews were conducted with two participants to capture any developments since the initial interviews. The study utilised an interpretive approach, which posits that reality can only be approached by engaging with collective constructions such as language, shared meanings, awareness, and devices. In interpretivism, knowledge often emerges near the end of the study (Research Methodology, 2017). This approach aims to construct original, richer insights and explanations of the world and social contexts without assuming there is a single correct form of truth or information (Saunders, *et al.*, 2016; Braun and Clarke, 2013). The study explores how social entrepreneurs in Nepal contribute to sustainable development and circular economy practices using a qualitative, interpretative approach. This approach is ideal for understanding complex phenomena from the perspectives of those involved, enabling the researcher to capture rich, contextualised insights. The research is exploratory, aiming to uncover underlying themes and patterns not immediately apparent in the existing literature. The primary data collection method used in this study was in-depth, semi-structured interviews. This method allowed for a detailed exploration of participants' experiences, thoughts, and motivations. The interviews were guided by open-ended questions designed to elicit comprehensive responses while allowing flexibility to delve deeper into relevant areas as they arose. Participants included individuals leading organisations or initiatives with a social mission, especially those emphasising sustainability and circular economy, who fund social enterprises and prioritise sustainability and impact, as well as policy influencers and experts such as researchers, think tank coordinators, and political figures knowledgeable about the sector.

The analysis involved a systematic approach to handling qualitative data, starting with transcribing, organising, coding, and categorising the data using NVivo software. Thematic analysis was employed, involving repeated reading of transcripts to identify and develop key themes. This process helps break down, compare, and categorise data to find meaningful patterns. Thematic analysis was chosen for its flexibility and simplicity, making it accessible even for those new to qualitative research. It allowed for the identification, analysis, and reporting of themes within the data, helping to summarise the key features of the dataset and produce a coherent final report. The data collected from interviews and documents was analysed using thematic analysis, identifying and reporting patterns within the data. All interviews

were transcribed, and the transcriptions were coded to identify key themes and concepts related to the roles of social entrepreneurs, their practices, challenges, and impacts. The codes were grouped into broader themes, reflecting the core aspects of the research questions. The themes were analysed and interpreted to conclude the role of social entrepreneurs in advancing sustainable development and circular economy practices in Nepal.

The research adhered to ethical standards to ensure the integrity and credibility of the study. The researcher obtained informed consent from all participants, ensuring they were fully aware of the study's purpose, procedures, and their right to withdraw at any time. The confidentiality of the participants was maintained, and the data were handled with care to protect their privacy (Richards, 2009). While the qualitative approach provides in-depth insights, it also has limitations, such as the findings not being generalizable beyond the specific context of the participants and the potential introduction of bias through self-reported data. These limitations are acknowledged and addressed through careful interpretation of the data.

Results and Discussion

The perspectives on the SDGs among these entrepreneurs vary, reflecting various levels of awareness and engagement. Two interviewees noted that while the SDGs provide a valuable framework, they may not fully capture Nepal's unique challenges and opportunities. They stressed the importance of adapting global goals to the local context. Among the 28 interviewed social entrepreneurs in Nepal, 16 are familiar with the SDGs, and the majority actively contribute towards these global objectives.

Interestingly, even among those unfamiliar with the SDGs, many entrepreneurs are intrinsically aligned with these goals through their work in areas such as poverty reduction, women's empowerment, and improving education quality. Recognition of Nepalese social entrepreneurs on the global stage, including honours as Ashoka Fellows and recognition by the Schwab Foundation and the United Nations, underscores the significant impact of their work in sustainable and socially responsible business practices. However, the alignment with the SDGs has been driven by the entrepreneurs' own vision and commitment rather than by direct support from government initiatives. This independence highlights the vital role of civil society and private initiatives in advancing sustainable development in Nepal, often addressing gaps left by public sector efforts. The findings of the research were grouped into five themes, and each of them is discussed below.

Social Entrepreneurs Promote Inclusive and Sustainable Economic Growth

Social entrepreneurs in Nepal are at the forefront of leading a genuinely sustainable way of life. They utilise their courage, talent, skills, and resources to improve society. Social entrepreneurship moves beyond mere charity as these individuals study the situation and become masters of their cause, dedicated to making a positive impact. They advocate for justice, equality, humanity, and the rehabilitation of the most vulnerable members of society. It is commonly assumed that significant social change necessitates substantial resources and investments. However, individuals driven by passion, creativity, and an entrepreneurial mindset have succeeded in bringing about significant, systemic, and

sustainable community changes despite limited resources, creating something out of nothing (Praszkier & Nowak, 2012), which seems particularly true in the context of Nepal.

Social enterprises also focus on improving livelihoods in impoverished areas, responding to the adverse effects of outward migration by generating employment opportunities that the government alone cannot provide. The largest corporations, primarily driven by profit, often neglect sustainable societal change, leaving a gap that social entrepreneurs seek to fill. One notable initiative involves a social enterprise run by visually impaired individuals, which sustains itself by training more blind people in massage therapy and opening new clinics to employ them. Social enterprises also prepare youths, women, and marginalised groups with various skills for different sectors, encouraging them to learn traditional arts and skills. Additionally, social entrepreneurs train youth and farmers and introduce modern tools and techniques to enhance productivity and income. As a result, thousands of jobs have been created for people with disabilities, trafficked women, war returnees, and older individuals, allowing them to utilise their skills and expertise. Through their efforts, social entrepreneurs are transforming communities and promoting entrepreneurship that leads to lasting social change. Their approach emphasises creating value, fostering independence, and encouraging sustainable practices, aiming to make a meaningful and enduring impact on society. They establish ventures, offer fair wages, and support microenterprises and microfinance to help people become self-reliant. They encourage the use of local resources for livelihood projects and create income-generating programmes, particularly in tourism, which employs many locals.

Since the constituency in need is actively engaged in the process, they generate economic and social value for themselves. Thus, the target group themselves produce income-generating projects such as yak farming, cheese making, papermaking, beekeeping, mushroom farming, organic vegetable farming, cloth making, rabbit farming, tea farming, fishery, and other projects on small scales. Social entrepreneurs also design and market the products made by disabled people and artists who are not on the radar. They design and execute projects to empower women and livelihood projects. They reinvest the profit to open more branches and impact more people. Creating economic opportunities is the common motive of all social entrepreneurs. Social enterprises close skills and gender gaps, provide free quality education to children in rural villages, create sustainable products and services, eliminate genderbased violence, improve the quality of life, and promote sustainable agriculture. Most importantly, they are helping people move from aid to enterprise and breaking the cycle of dependence on foreign aid.

Therefore, research supports the idea the idea that social enterprises address marginalised individuals and communities (Haugh & Talwar, 2016; Parthiban *et al.*, 2020; Qureshi *et al.*, 2021).

Despite the positive impact of social enterprises, some social entrepreneurs' critique traditional development agencies and NGOs. 'Interviewee 23' highlights the inefficiencies and short-term focus of many donor-funded projects, which often fail to create lasting change and sometimes increase dependency. Social entrepreneurs are seen as critical of these practices, preferring to foster self-reliance and long-term sustainability. They believe that many large organisations prioritise reporting and expenditures over meaningful impact. Therefore, they offer corporate training as a revenue-generating initiative that is aimed at leaders of NGOs, INGOs, government bodies, and academics. The purpose is to educate them on how to integrate sustainability into their organizations. The revenue generated from this programme subsidises other programmes, making them more accessible to marginalised people.

'Interviewee 24' acknowledges that NGOs play a role in focusing on rights and legal frameworks, though there is room for greater synergy between NGOs and the private sector. However, social entrepreneurs aim to avoid the pitfalls of aid dependency by fostering skills and independence among their beneficiaries. Thus, social entrepreneurs have emerged in tandem with governments' and the public sector's growing incapacity to address the complex demands and challenges of social welfare (Stephan *et al.*, 2015; World Bank, 2017). Overall, social entrepreneurs play a crucial role in fostering entrepreneurship, sustainable living, and self-sufficiency. Their work involves empowering communities to support and uplift one another. They provide training and skill development programmes for various groups, including youth, marginalised women, the elderly, and people with disabilities, to help them become independent in the long term. They aim to break the cycle of dependency on aid and donations that has been prevalent for the past 50 years in the development process. Individual social entrepreneurs have successfully transformed over 100 communities. Their focus is on promoting sustainable entrepreneurship among the target groups and working towards generating income from their ideas to bring about positive social changes.

The research suggests that even though social enterprises in Nepal are still in the preliminary stages, there is a shift from prioritising profit to prioritising mission, with businesses placing people and the planet before profit. These enterprises tailor their projects to the needs of the communities and raise funds through a business model. Even social enterprises that previously relied on external funds are now striving for self-sustainability and embedding sustainability in their business models. Interestingly, NGOs in Nepal are rebranding themselves as social enterprises, partly to escape the negative connotations associated with NGOs. These organisations are now adopting business models to generate funds for their social missions. Therefore, SE blurs traditional boundaries between the public, private, and non-profit sectors, advocating for hybrid models that combine for-profit and non-profit activities, as suggested by Johnson (2000).

Social Enterprises Work to Empower Women and Girls

In Nepal, women often face significant discrimination and violence from birth, reflecting deeply ingrained gender inequalities. This includes severe practices such as selling daughters into labour, forcing women into brothels, and enduring domestic violence. Although the 'Sati' system has been abolished, other harmful practices like banishing women to 'menstrual huts' during their periods persist. These issues negatively affect women's health, education, and overall well-being, leading to problems such as malnutrition and, in extreme cases, death. Social entrepreneurs are playing a crucial role in addressing these challenges. They focus on advocating for gender equality and empowering women through various initiatives, including education, economic opportunities, leadership training, and raising awareness about human rights. By doing so, they help women gain financial independence and selfreliance, enabling them to support themselves and their families. These social enterprises offer diverse programmes tailored to the needs of women. They provide literacy classes for women aged 15–45, training in hand knitting, and other skills relevant to market needs. For example, a longstanding social enterprise established over thirty years ago employs around a thousand women in various crafts and skills, from weaving to block printing and tailoring, and has now expanded to include more than nineteen skill categories. The once-illiterate women are now proud graduates in foreign countries and travel for conferences and seminars. Once, they were unable to afford nutritious food during pregnancy, but now they live a comfortable life with high

self-esteem. These programmes aim to equip women with skills beyond traditional labour-intensive jobs, preparing them for broader opportunities in the workforce. In addition to vocational training, social entrepreneurs work to combat issues like early marriage, illiteracy, and human trafficking. They educate women and parents about the dangers of early marriage and emphasise the importance of treating daughters equally. Preventive measures are taken to address the root causes of these issues, including health education on topics like breast cancer. Collaboration with civil society organisations and the government enhances these efforts, providing additional training in areas such as accounting and management. This broadens the opportunities available to women and strengthens their capacity to achieve financial independence. Social entrepreneurs also work to rehabilitate women rescued from brothels, helping integrate them back into society—a gap that many NGOs and INGOs struggle to fill.

These efforts have had a significant impact on the lives of many women. For instance, training programmes in cooking, marketing, and teaching have enabled women to contribute economically to their families and communities. The women involved have gained confidence and are now multi-skilled, some even becoming trainers. They have formed networks and groups, fostering a sense of unity and strength, which has been instrumental in scaling their businesses. While there are challenges, such as securing funding for women-led businesses, there is a growing interest from impact investors. These investors support women-founded enterprises, helping them incorporate business acumen and achieve sustainable success. Social entrepreneurs view women as more likely to reinvest in their communities, driving long-term change.

Therefore, social entrepreneurs are considered important implementers of the SDG. Social entrepreneurs focused on education, healthcare, microfinance, and socio-economic development in rural areas have impacted millions (Bornstein and Davis, 2010). SE directly contributes to sustainable development goals and thus offers inputs for sustainable business practices accepted by society, as suggested by Muralidharan and Pathak (2018). They have developed new methods to provide essential services that address the unmet needs of the population, which have not been adequately addressed by the government and traditional markets. Some of these entrepreneurs are involved in community-led initiatives to support the SDGs. A study showed that over 61% of social entrepreneurs are aware of the SDGs and are striving to contribute to their achievement. However, more than 30% of social entrepreneurs were not familiar with the SDGs, and the remaining percentage did not consider them relevant. The United Nations has recognised and awarded certain social enterprises for their innovative approaches to addressing these goals.

Nevertheless, social entrepreneurs are at the forefront of the circular movement, spearheading innovative solutions to societal challenges through unique business practices. Their contributions to the circular economy are significant and multifaceted: they advocate for circular business models, address the social risks associated with them, and harness the potential for positive social impact. These entrepreneurs are redefining business standards and forging strong connections with communities globally. Their initiatives ensure that circular business models are not only sustainable but also socially inclusive and beneficial. A new era of collaborative SE focused on creating systemic change on a large scale is emerging. They solve complex problems with confidence, converting adversities into opportunities. They tend to solve the problems in the areas covered by the SDGs (Velath, 2016) and work

to alleviate poverty (Hackett, 2010; Mair *et al.*, 2012; Sutter *et al.*, 2019). Finding of the research supports this statement.

Social Entrepreneurs are Dedicated to Improving the Quality of Education

Social entrepreneurs are passionately committed to improving the quality of education in Nepal, addressing critical gaps in both private and public schooling systems. Private education in the country is often prohibitively expensive, while government schools frequently struggle to provide a modern, relevant curriculum. Despite the efforts of international NGOs claiming to support millions of children, many government schools continue to underperform, with a staggering 74% of students failing their higher secondary exams. In regions like Karnali, the dropout rates are particularly alarming. To combat these challenges, social enterprises are taking innovative steps to understand why students drop out, offering scholarships, and supporting teachers. For example, one enterprise provides essential educational supplies to 200 students. In areas where private schools are scarce, some social entrepreneurs have set up free private schools. One such initiative, operating in three districts with plans to expand to thirty more, has adopted the "Maya Model." This model involves parents contributing their labour to the school instead of paying fees and includes a diverse curriculum covering sports, agriculture, and global culture. Another enterprise is enhancing technological infrastructure in rural schools by introducing internet access, computers, and e-libraries. This project not only connects local schools with global educational resources but also publishes educational materials to enrich learning. Collaboration with local partners amplify the impact of these initiatives. For instance, projects working with children in brick factories and involving local youth in teaching and sponsorship efforts are making a difference. Overall, these social entrepreneurs are breaking down barriers to education and providing inclusive, high-quality learning experiences, equipping future generations with the skills and knowledge they need to succeed. Even washing programmes in toilets have resulted in a higher attendance of girls in government schools.

An example of a notable initiative is a Waldorf-inspired school in Nepal. The school integrates the Waldorf education model with local culture and values to foster self-confidence, creativity, and readiness for the future among students. The school emphasises hands-on learning and incorporates nature into its curriculum, including activities and a natural bamboo playground. The teaching staff trained in Waldorf education—some of whom received training in Switzerland and India—benefits from ongoing support and training from international Waldorf professionals. Scholarships are available for families unable to afford the monthly fees to ensure that education is accessible to all. Furthermore, volunteers from around the world teach children different skills and languages while their parents are always present to build their confidence.

These social entrepreneurs not only run educational projects but also engage in agricultural initiatives to support their endeavors. For instance, they participate in organic farming, construction, raising livestock, and tree planting, with parents volunteering in these activities. A few entrepreneurs have successfully initiated free-range chicken farming, organic farming, and handicrafts, generating significant profits to support the school. Additionally, the schools offer voluntary programmes and host tours to generate additional income, ensuring the sustainability of their educational missions while also providing support

for disadvantaged students, such as orphans and those from outside the local area, by offering them free accommodation.

By addressing these educational challenges head-on, social entrepreneurs in Nepal are not only providing immediate solutions, but they are also laying the groundwork for long-term, positive change in their communities. These educational institutions are well known now and have been awarded nationally and internationally for their innovative approach to education. Moreover, the business model can be replicated for a greater impact in Nepal and beyond the border.

Social Enterprises Tackle Health Issues in Communities

In rural Nepal, inadequate healthcare services and economic challenges contribute to high mortality rates from diseases like cholera. Government health centres are often under-resourced and unreliable, leading to significant issues, including high maternal and child mortality rates. Many people, lacking awareness of hygiene and sanitation, face frequent epidemics. Due to limited education and financial resources, many turns to traditional healers instead of seeking care from qualified medical professionals. Social entrepreneurs are addressing these challenges through several innovative approaches. Small health clinics are being established in areas without government health posts connected to urban hospitals through telemedicine. This setup facilitates remote consultations and provides access to essential healthcare services. Improved cookstoves are being introduced to reduce respiratory diseases caused by smoke from traditional cooking methods. These stoves enhance ventilation, reduce the time women spend gathering firewood, and lower CO_2 emissions, thus improving overall health and reducing the environmental impact. Birthing centres are being built in rural areas to improve maternal care, and sanitation practices are being promoted. Educational programmes on health and hygiene are conducted for schoolchildren and remote communities, leading to better health outcomes.

A notable example is the local production of lenses, which began in 1995. Initially, lenses were priced at $150, but a community-based SE reduced the cost to $5 through local production. They developed a 'Low-Cost, High-Quality, High Volume Cataract Surgery' system and a 'Robin Hood' model, where those who can afford to pay do so while others receive free services. This model has enabled the expansion of eye care centres, particularly in mountainous regions, and the organisation has conducted free cataract surgeries for over 120,000 people. Cataract surgeons from all over the world are trained in this organisation, and the renowned cataract specialist is known for his significant impact not only in Nepal but in several other countries. Traditional healers are being trained in eye care to identify cataract cases and refer patients for treatment. Media and community outreach are used to promote cataract surgery and ensure underserved populations receive the necessary care. Profits from lens sales support these initiatives, contributing to their sustainability.

Water, sanitation, and hygiene (WASH) programmes are being implemented in government schools, leading to increased attendance. The goal is to expand these programmes to 50 more schools annually, ensuring that new schools have access to water filtration systems and clean toilets. Efforts are underway to raise awareness about menopause and andropause, highlighting the hormonal changes that occur in both men and women as they age. This education aims to improve the well-being of senior citizens by

addressing previously overlooked health issues. These initiatives collectively enhance health outcomes, improve quality of life, and contribute to the overall sustainability of healthcare services in rural Nepal.

Social Enterprises Tackle Environmental Issues and Promote a Circular Economy

Social entrepreneurs in Nepal are developing business models that prioritise social inclusion, ecological sustainability, and economic viability. They emphasise the importance of reusing, reducing, recycling, and respecting natural resources. Their work includes investing in and researching clean energy solutions to prevent deforestation for firewood. These entrepreneurs also provide training in sustainable agriculture, eco-architecture, organic handicrafts, organic farming, and forest conservation. In their agricultural practices, social entrepreneurs use sustainable and organic farming methods without pesticides and harmful chemicals. For instance, they produce natural, organic fertiliser on-site for every coffee plant. Their farms are rich in greenery and livestock, encouraging local community involvement in organic coffee plantations, which in turn creates employment opportunities. They distribute free saplings, offer counselling on coffee cultivation, prepare organic compost, and provide guidance on preventing coffee diseases. This not only supports sustainable coffee farming but also contributes significantly to forest and soil conservation, as coffee plantations benefit from the presence of shade trees.

Interviewee 6 has developed various income-generating programmes, such as yak farming, cheese making, paper making, handicraft production, beekeeping, mushroom farming, organic vegetable farming, cloth making, rabbit farming, tea farming, and fishery projects. One entrepreneur operates a commercial eco-café to generate revenue for their foundation. This café not only serves as a business model but also focuses on revitalising the soil to improve food quality and educating the community about sustainable practices in agriculture, eco-architecture, and organic handicrafts. The organisation prioritises reducing waste, recycling materials, and respecting natural resources to create a sustainable environment. They construct buildings and schools using locally available natural resources, such as bottles, and employ sustainable energy sources like solar power and biofuel. Additionally, these entrepreneurs are committed to protecting wildlife and bees. Despite setbacks, such as those caused by an earthquake, they continue to work towards minimising the use of LPG gas and maximising the production of biofuel and other sustainable energy sources. Social entrepreneurs in Nepal are innovators finding profitable ways to deliver solutions such as clean green energy, affordable health care, complete education, improving the quality of work and life, managing the environment, and managing the economy sustainably as outlined by the SDGs. SE is identified as an effective way to meet global sustainable development and well-being in general (Seelos & Mair, 2005a), as it considers both economic inequity and social issues as mutually dependent.

The use of locally sourced raw materials is another critical aspect of their work, aimed at making production more efficient and reliable. For example, Interviewee 15 focuses on environmental care and promoting community-based eco-tourism. Interviewee 1 targets consumers who are aware of global issues, designing products that are organic, ethical, and fair-trade, and sharing the stories of their makers. Interviewee 7 connects individual health and happiness with the natural environment and aims to inspire sustainable living practices to ensure the planet's longevity. He designs eco-friendly programmes that foster sustainable community development, emphasising a strong connection with the local ecosystem and the broader environment in Nepal. Social enterprises often contrast with commercial businesses,

which may overlook local environmental impacts and global warming. For instance, Interviewee 5 manages an agricultural farm, a travel business, and a poultry farm, cultivating organic crops like oranges, avocados, lychees, mangoes, and tea plants to support the operation of a free private school. Plans include expanding agricultural land to plant more crops and trees. Another entrepreneur, Interviewee 3, runs an organisation that provides simple rainwater harvesting solutions, including biosand filters to purify underground water and make it potable. The promotion of eco-tourism, led by figures like Interviewee 15, is also a key focus, with initiatives that prioritise environmental protection and local community benefits. Some social entrepreneurs design products that are organic, ethical, and fair-trade, while others, like Interviewee 7, create programmes that help individuals connect with their natural environment, promoting sustainable development. Innovations such as clean cookstoves and rainwater harvesting solutions further reduce environmental impact and improve community health. There are social enterprises that focus on recycling old clothing and fabrics to benefit the community. These organisations collect donations of clothing from individuals who wish to contribute. They then alter or upcycle these items, making them available for sale at nominal prices. Clothing is often distributed in rural areas where people might struggle to afford new garments and are vulnerable to cold weather conditions. By providing access to affordable clothing, these enterprises not only help to meet basic needs but also support sustainable practices by reducing waste. Additionally, they often reinvest any proceeds into community projects, further enhancing the social and economic well-being of the regions they serve.

These social entrepreneurs also play a crucial role in protecting the environment and conserving natural resources by reducing CO_2 and greenhouse gas emissions. They utilise raw materials that would otherwise go to waste, thus generating sustainable income for the community. For example, in Taplejung, women have started weaving baskets from discarded cardamom stems and plants, creating additional income streams from the region's abundant cardamom crop. Social entrepreneurs are motivated by a desire to benefit both people and the planet. Their business models are designed not to exploit resources but to sustain them, often in collaboration with NGOs working on environmental causes. They practice waste segregation, apply the cradle-to-cradle concept, and use recyclable materials, like paper cups in cafeterias. By promoting environmentally sustainable business practices, these social entrepreneurs view the Earth not just as a resource but as a vital source of life. Therefore, social entrepreneurs work to sustain the environment (Belz & Binder, 2017; Calic & Mosakowski, 2016).They have a passion for starting something sustainable and value the local market more than the international market. Social entrepreneurship in Nepal embraces Dees' description of social entrepreneurs, as Dees (2004, p. 17) argues: "Successful social entrepreneurs will use the most effective structures, strategies, and funding mechanisms to achieve their social objectives." Also, there are only 10% of women entrepreneurs in Nepal at this point, but in the context of SE, there are an equal number of women social entrepreneurs, if not more, which is a surprising result of the findings.

Conclusion

Social entrepreneurs in Nepal are creating significant social, economic, and ecological value through their enterprises. These ventures aim to tackle issues such as poverty, education reform, sustainable livelihoods, and the empowerment of women and marginalised groups. They focus on bringing about long-term, inclusive changes by working closely with communities, promoting sustainable farming, connecting remote areas through technology, and addressing social stigmas. To achieve their social

missions, they collaborate with a wide range of stakeholders, including the government, like-minded partners, civil societies, family members, volunteers, and development agencies. While collaboration is crucial for making a larger impact, these entrepreneurs ensure that their partners share similar ethics and values.

These entrepreneurs prefer to co-create solutions with communities, ensuring long-term ownership and sustainable change. They don't just raise awareness about issues like education, health, and early marriage but work to solve the root causes. Social enterprises maintain financial sustainability by keeping administrative costs low, wisely using resources, especially during emergencies (such as the 2015 earthquake) and diversifying their income streams. They often employ business strategies like cross subsidising their social missions with commercial activities and using a barter system to minimise costs. Social enterprises in Nepal operate with a bottom-up approach, viewing those in need as potential value creators and change agents. They design their programmes based on the specific needs of communities, moving away from traditional methods and focusing on local solutions. This inclusive approach recognises that individual and community development cannot happen in isolation.

However, social entrepreneurs in Nepal face several challenges. These include securing various types of capital (natural, human, social, intellectual, and financial), changing the community mindset from grant dependency to a growth-oriented approach, and overcoming excessive bureaucracy. Other challenges include inadequate early-stage funding, a lack of infrastructure, insufficient raw materials and machinery, poor logistical services, difficulty in meeting quality standards, and a shortage of technical expertise. Additionally, there is a significant challenge in altering the social mindset that depends on aid and in navigating the country's evolving policy landscape, which lacks specific provisions for registering social enterprises.

For social enterprises to thrive, they need support through government and organisational promotion, systems, and networks tailored to their development. This includes practical training, market research, and funding at the individual level, as well as well-established policies and supportive guidance at the ecosystem level. The integration of Sustainable Development Goals (SDGs) into regional and local planning is still a work in progress, and the government has not yet fully aligned these goals with the needs of social entrepreneurs. The current regulatory framework in Nepal lacks specific recognition for social enterprises, with many operating under various forms such as NGOs, private for-profit entities, and fair-trade businesses. As global recognition of social enterprises grows, Nepal's government is gradually acknowledging their importance, but further evolution in policies and frameworks is needed to fully support their unique role in addressing the country's social and economic challenges.

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9b. Collaboration and Co-creation for Sustainability, SDGs Initiatives and Scale of Governance

Abstracts

Submission ID: 22

Beyond Neoliberalism: Addressing the Challenge of Sustainable Consumption for Governance and Policy Development

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Abstract

'Green growth' has been established by industry, governance and society as one of the major incentives and motivators for the betterment of the environment, allowing companies to shift their focus in a sustainable manner. This can provide consumers with a plethora of information which, in some cases, leads to difficulties in decision making. While this approach is proposed by governing entities, its final execution befalls on consumers and corporations alike. This study aims to advance understanding of decision making within governments, corporations and consumers which will allow for a better integration of the 'Green growth' approach. This will be addressed by utilizing an established framework which distinguishes behaviour in society as falling into one of three categories: the utilitarian, social/psychological and/or systems of provision/institutional approach. By establishing these relationships, a more thorough understanding of collaborative action in society may be achieved. This could provide a basis on which to leverage individual environmental motivation from a policy context. An analysis of 'the expand or perish' approach widely proclaimed by the contemporary economic system will be undertaken by evaluating the incitements that motivate enterprises to push the green growth approach even further. These aims will be achieved by the employment of both bottom-up (consumer) and top-down (regulations and policy) data collection methods. By using data from both of these perspectives, it is hoped to obtain a better understanding of the interplay of consumption and governance/regulation. This in turn will facilitate a more thorough review of current policy tools designed to promote green growth, as well as identify gaps in current legislation.

Submission ID: 83

Co-Creation in a Quintuple Helix, the Art of Including Natural Environments of Society in a Living Lab That Includes Different Types of Stakeholders and Monitoring the Quality of This Process of Co-Creation

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Abstract

In the last decade, co-creation has not only become a widely used concept in academic discourses but also in public policies that aim to tackle so called 'wicked problems', a term coined in the 1970s (Rittel & Webber, 1973) that is nowadays often interchangeably used with societal challenges or SDGs. This focus on tackling societal challenges by governments in collaboration with citizens opened the door for new concepts such as 'living labs' in 2006 (Rădulescu *et al.*, 2022) 'policy labs', 'innovation hubs', 'co-creation labs' and recently 'public sector innovation (PSI) labs' (Fuglsang & Hansen, 2022; Hansen & Fuglsang, 2020; McGann *et al.*, 2021; Torvinen & Jansson, 2022). The use of labs has also been addressed by the OECD in their publication on innovation in the public sector outlook to make policymakers aware of the importance of public sector innovation (OECD, 2015).

Literature research in combination with questionnaires into these types of labs showed that the definitions of PSI labs are quite 'fuzzy', sometimes even interchangeable and are heavily dependent on the national, regional and local context as well (McGann *et al.*, 2018). In addition, research also showed that it is difficult to distinguish good practices, l*et al.*one to define specific conditions for these good practices (Meister Broekema *et al.*, 2022). In addition, an inductive analysis of a large number of EU policies shows that on a conceptual level, the EU uses specific interpretations of social innovation (Moulaert & MacCallum 2019) and co-creation in open innovation ('Open Innovation 2.0' 2013), influenced by the concept of triple- and quadruple helix innovation in which universities, governments and enterprises are collaborating, sometimes for the benefit of society as a whole (Carayannis & Campbell 2012; Leydesdorff 2010). Co-creation as such is used merely as a criterion within social innovation projects that aim to tackle societal challenges, therefore neglecting the quality of the process of co-creation (Meister Broekema *et al.,* 2021).

In order to maximise the impact of co-creation and be able to tackle societal challenges such as climate change, it is therefore essential to focus more on the quality of co-creation between 4 helixes in these processes and include the environment as a fifth helix (quintuple helix innovation as defined by Carayannis et. al. 2012). In the talk, a novel framework will be presented that will support collaborators in a project that aims to tackle a societal challenge by including the right stakeholders at the right time and monitor progress and satisfaction continuously (Meister Broekema 2023) in a quintuple helix setting.

This presentation will contribute mostly to SDG 17 (partnership for the goals) and SDG4 (Quality Education) and is best suited for SDG13 (Climate Action). The insights can be used to enable multiple stakeholders from government, education and research, enterprises and citizens within a natural environment (mountains & oceans) to co-create in a quintuple helix setting, maximising their impact on climate change and strengthening partnerships for this goal.

Submission ID: 188

Collaborative Value Creation in the Specialty Coffee Industry: A Case Study of Competitor Cooperation for Sustainable Development

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Abstract

This paper explores the potential for competitors to collaborate and transform neglected industry values into new customer value. The research focuses on the Specialty Coffee industry in Colombia, aiming to understand how competitors can drive sustainability through collaboration. Resource constraints can limit smaller firms' ability to adopt sustainable strategies independently. However, addressing sustainability challenges within industries often requires collaboration among competitors to integrate neglected values into their business models. Coopetition involves collaboration and competition among competitors to achieve common goals, emphasizing the strategic use of shared resources and capabilities. Values-based networks emphasize collaboration driven by shared values to create innovative and sustainable business models. However, gaps remain in understanding how competitors can effectively collaborate to address sustainability challenges and create value. The study employs a qualitative small-N case study method and the Congruence Analysis (CON) approach to compare and contrast coopetition-based and values-based business model network theories. Interviews were conducted with 17 owners and managers of Colombia's Specialty Coffee Shops Network. The interviews explored perspectives on sustainability challenges, value adoption mechanisms, collaboration among competitors, and perceived benefits of the network. The analysis revealed complementarities and convergences between coopetition-based and values-based business model network theories. Competitors collaboratively addressed sustainability challenges, adopted neglected industry values, and created new customer value through a networked approach. Interactions among key factors, such as sustainable challenges, values-based networks, value creation with competitors, and the transition from values to tangible value, illustrate the collaborative dynamics driving a values-based network among competitors. The study contributes to understanding how competitors collaborate to address sustainability challenges and create value through a values-based network. For academics, the findings enrich the understanding of coopetition and values-based networks in driving sustainable business models. Practitioners can leverage coopetition for business model development and should support coordinated efforts to address sustainability challenges.

Relation to Conference Theme: This paper directly addresses the theme of the 30th ISDRS Conference 2024 by focusing on collaboration and co-creation between societal actors in the context of sustainable development, specifically within the Specialty Coffee industry in Colombia. It contributes to the conference's goal of discussing principles, programs, methods, and applications of collaboration and co-creation among universities, the public sector, industry, and civil society. The paper explores how competitors in the industry can collaborate to address sustainability challenges and create new customer value, aligning with the conference's objective of encouraging contributions that examine enablers, barriers, empirical cases, and theoretical perspectives on collaboration and co-creation for sustainable development. "SDG+Target: 12.6."

Submission ID: 319

Nepal's Zero Hunger Journey: Challenges and Opportunities

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Abstract

Eliminating hunger is a top priority globally and also in Nepal.

Zero hunger is one of the most important among the Sustainable Development Goals (SDG). Indeed, it is not acceptable to have people suffer from hunger in this modern age. Governments throughout the world have committed to achieving Zero Hunger by 2030. Nepal is no exception and has made this a high priority.

Using a variety of secondary data, this paper provides an analysis on the trend of food security and nutrition in Nepal over the last few decades and its position in the regional and global context. It also provides an analysis on various factors contributing to food security. The main data used for the analysis include National Living Standards Survey (NLSS), national accounting, and agriculture census by the National Statistics Office of Nepal; agriculture statistics by the Ministry of Agriculture; global hunger index by the Concern worldwide, and State of Food Security and Nutrition in the World (SOFI) by FAO, WFP and UNICEF.

The analysis reveals that Nepal has made significant progress in improving the food security and nutrition of its population in the last few decades. This is reflected in the improving trends of food consumption, improvement in the global hunger index, reduction in prevalence of undernourishment and stunting of children under the age of five. Despite these improvements, the food security situation in Nepal remains vulnerable, as the improvement in consumption is mainly caused by an economy highly dependent on remittances of migrant workers. The agriculture productivity remains relatively low and the country depends on significant imports to meet its food needs, despite more than 60% of the population being engaged in agriculture. Furthermore, the agriculture sector is likely to be further affected with the impact of climate change. Opportunities exist in increase in agricultural production through improved farming and better inputs; diversifying livelihoods, coordinated approach to food security and nutrition, and more targeted social protection programmes. Though achieving zero hunger by 2030 (SDG2) seems no longer attainable, it is quite possible to have significant further improvement from the current situation.

Full Papers

Submission ID: 156

Double Blade of Sustainability: International Agreements and Local Applications of International Companies

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Abstract

Sustainability has been scrutinized through previous international studies with differing linkages such as The Our Common Future, The Rio Congress, Agenda 21, and SDGs for 2030 for protecting humans, and the environment. Some International companies do not observe international treaties in other countries' land and applications on them. Power can be evaluated with different criteria. This paper covers the double blade of sustainability through discussions on using power and application on others' land, current rules in their country, and applications on others' land in line with or against legal procedures. Capitalism has been forging violent mining actions recently. For sustainability, they have to be scrutinized and results put forward properly to take action for the future.

This paper scrutinizes the gold mining experiences in South Africa, Canada, the USA, Turkey, and other countries. The findings are based on the literature review and observations. The main necessity in evaluations is not to be biased and to be able to see together the double side of sustainability even if the effects are hidden or shadowed. If this vision is not possible, international agreements and local applications can contradict and be in dilemmas. This will be putting sustainability issues in danger and halting it. Sometimes they may increase local responses much stronger.

Introduction

Sustainability has been scrutinized through linkages to different issues. When we look at the historical process of discussion developments, there are important progress examples such as the publication of The Our Common Future and previous preparative studies were important achievements (1987 and before). Then the Rio Congress in 1992 and framing the Agenda 21 were other cornerstones. Agreements on the SDGs especially for 2030 are assigned as recent important international agreements.

However, these agreements are not the sole rules to follow. There are other signed agreements for the protection of humans and the environment. They are visible at national, and local levels and in formal or informal ways. We are becoming aware of them only if we follow up on the processes or analyze details of extraordinary events. Those are usually hidden.

Berkes and Folke mentioned the link between social and ecological systems in their edited books (1998). This has been pointed out by Keleş as well for quite a long time ago in Türkiye. The recent developments of values of urban and environment were important for him. The most important thing was the equal importance of effective interaction of right and duty. He describes them with horizontal and vertical responsibility and duties by referrals to intergenerational transitions, people, communities, states, and governments (Keleş, 1993, pp.23-33).

For this reason, the responsibilities and resiliencies of communities are important as Kruse et. al. reveal in conceptualizing community resilience to natural hazards (2017). However, this issue cannot cover only the frame of natural hazards but rather man-made, natech, and technical hazards as well. In this sense, mining activities and related experiences can be thought of. Sometimes our thoughts and visions might require recalling as Adair calls "*activist foundations of sociology*" (Adair, 2014).

Some International companies do not observe international treaties in other countries' land and applications on them. In this sense usage of power can be evaluated with different criteria.

This paper will evaluate the double blade of sustainability in the context of using power and application on others' land; the present rules in their own country, and their applications on others' land in line with or against local or international legal procedures.

Capitalism has been forging violent mining actions recently. For sustainability, they have to be scrutinized and results put forward properly to take action for the future. Therefore, this study focuses on especially some mining and gold mining experiences worldwide.

The gold mining experiences will be derived from South Africa, Canada, the USA, Türkiye, and other countries. Thus, the paper will indicate a double blade of sustainability by exploration of legal frames and applications. These double-blading effects are sometimes shadowed or hidden one way from one side. Through proper evaluation of the situation, the necessity comes to light not to be biased and able to see together the double side of sustainability. If this vision is not possible, international agreements and local applications might conflict. This will be putting sustainability issues in danger and halting it. Sometimes they may increase local responses much stronger. The paper will bring out these dilemmas through case studies.

The paper consists of five main sections. The introduction section pays attention to the importance of the topic. The second section summarises a short literature review. Then the third section frames the methodological process of the study. The fourth section reveals results and discussions of detailed reviews of case studies. The final section covers the conclusion.

Literature

Barbier's «three-pillar conception of (social, economic, and environmental) sustainability is commonly represented by three intersecting circles with overall sustainability at the center» (Purvings, Mao, Robinson, 2019, p. 687).

Pillars, concentric circles, or intersecting circles are the common evaluation ways of sustainability. In the early academic literature of the "economic status quo from both social and ecological perspectives on the one hand, and the quest to reconcile economic growth as a solution to social and ecological problems on the part of the United Nations on the other" (Purvings, Mao, Robinson,2019, p. 683).

As Frederiksen and Banks create a linkage between SDGs and mining. They evaluate "Can Mining Help Deliver the SDGs: Discourses, Risks and Prospects" (2023). One may think that SDGs-related areas are

aging, civil society, cooperatives, disability, employment, family, indigenous peoples, poverty, social inclusion, and youth. Sustainable development's 17 main goals are namely: no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation, and infrastructure, reduce inequality, sustainable cities and communities, responsible consumption, and production, climate action, life below water, life on land, peace justice and strong institutions and partnership.

Moreover, we have to think underneath detailed articles about each goal. Reflections can be traced in literature examples in the short discussion details below.

One should think about some of the following questions. Who will be beneficiaries of these sustainable development goals, how benefits are achieved and can be shared between partners, how will the process be monitored, and who will be responsible for that? Many questions should be answered in the case of mining experiences. There are detailed literature groups on mining, sustainability, SDGs, and power relations however, the frame of the conference limits discussion details. Therefore, they will be discussed in detail in future articles.

Since the last several conference discussion results reveal that SDGs and achievements are not achieved properly due to the complexity of the reasons. The results put SDGs and applications' validity and reliability in question.

However, these can be added as approaches to studies on these areas and attempts to merge different areas. This is changing and the importance of follow-up studies on the processes and results has been coming forward.

Methodology

This paper scrutinizes the gold mining experiences in South Africa, Canada, the USA, Turkey, and other countries.

The findings are based on the literature review and observations in the frame of legal rules and local applications. The findings and discussions are limited. Detailed discussions will be published further in the future.

Results and Discussion

I have been mentioning the linkage of conditions in the local areas, events, the necessity of interconnectivity of institutions, responsibilities, process evaluations, international treaties, and disasters (Öner, 2006, 2008, 2024)

This section prevails on results and discussions based on the case study examples.

I will begin with an example of an interview with a known energy company CEO to emphasize the complexity of tracing companies and their activities in different areas and locations. This link appears with the discussion flow with the process analyses and summary of it took my attention while writing my

presentation. The discussion was on the “Situation of Energy Companies” - The David Rubenstein Show- on the Bloomberg 2.05.2024, 23:25 Peer to Peer Conversations-With Mike Wirth (Chevron Chairman And CEO)

Rubenstein mentioned current Energy Production and the New Profıt Tax in the USA. Earlier Carter's time and now- difficulties of working in different locations came forward in the discussion. Wirth mentioned Petrol’s Biggest Resource for the USA is Canada and the Middle East is a new area. But New areas for the future are like to be the Mexican shore. The company has 145 years past and Rockefeller’s investment in the company's early years was importantly emphasized. The CEO indicated failures in Africa due to civil wars and shifts in working processes (discovery of new sources or working in production). This was explained by giving explanations by creating linkages with personal conditions and conditions of local land other than his country. He mentioned his preference for carbon energy or turnıng to renewable energy and concluded that there are more solutions, not one. The necessity is investing in many areas for the future. This discussion prevails in the interest of international companies and their widening interest and investment areas. This indicates the necessity of tracing different activities and questioning interactions.

Rubenstein was questioning why people like energy but not energy companies. This was revealed with an answer to the benefit of energy and its consequences (2024).

Even in this short interview, there are many traces of linkages between SDGs, international-national and local conditions, innovations, economies, importance of location, and community conditions. Who can trace the results of the actions of these companies in their working locations other than themselves? What are the stories of the sides affected by them? These are several important questions there are others as well.

Ille was bringing forward ınternational joint ventures in industrial gold mining, corporate social responsibility, and harm production in Sudan, between 2006-2015. Violent conflicts and the requirement of proving they have no impact on the violent actions as external actors and internal. He uses the example of the La Mancha gold mining company and tracing local and international linkages (Ille, 2018). A peaceful environment is important for industrial actions, disasters, and monitoring them (Öner, 2008). However, inducing, and interfering parts of the violence is equally important. Sometimes conflicting times are used to formalize illegal applications in formal rules.

Graham discusses linkages between heavily populated high-rise cities and vertical deep mines (2020, pp. 287-288). He was giving historical processes by mentioning examples. Henry Veltmeyer- a new form of “*extractive imperialism*” a primitive capital accumulation form similar to earlier periods of colonialism.

As Graham summarises, Samarendera Das and Miriam Rose (Activists against mining activities)-the modern development concept backed by the World Bank, IMF, and UN indicates that the evolution of the human race is directly related to the consumption of mineral resources. This can be traced to the production percentage increase of cobalt %165, iron %180, aluminum %64, copper %42, etc.

Latin America and Africa are revealed as places of heavy mining activities. Graham emphasizes activities in Latin America by indicating an increase of delivered lands for use/operation privilege to overseas mining

companies. He exemplifies this by linkages between international treaties, actions of local power forces, and the reconstructed new structure of past colonialism. According to him, undergrounds of countries and continents, are distributed to the Global mining companies on the principles of legal treaties. This action has been taking place under the protection of state forces and paramilitary forces have been reconstructed as units of sovereignity in past colonialism.

Graham also gives an example from Peru. There is an increase in the rate of land transfers in Peru to Petrol companies (72 of the total land of Peru in 2008) and Colombia to mining companies (more than 450-4,77 million hectares). Graham calls this situation an "*Imperıalist Resource Grab"* (2020, p. 287-288).

Rem Kolhas's 2014 study and table of *elevators- the highest skyscrapers and deepest mining pits* in the world since 1850. According to this table, the highest skyscrapers are Kingdom Tower (2020-1008m Saudi Arabia), Burj Khalifa (2010-828m, United Arab Emirates), World Trade Center-Twin Towers (1973-417m, USA), Empire State (1929-381m, USA), Eifel Tower (1887-324, France), Equitable Life (1870). The deepest mine pits are as follows according to their depths: Tautone (1962-390m. South Africa), Mponeng (1962-3200m, South Africa), Moab Khotsong (deepest gold mine 1992-3054m, South Africa), St. Adalbert (1875-1875m, Czechia), Sanjose (2010-622 m. Chile) (Graham, 2020, pp. 290-291).

Graham indicates the necessity and linkage of going deep to excavate sources to construct the highest buildings by referring to Dan De Quille. Journalist Dan De Quille in 1877 revealed the debate on the linkage of technology set on the excavation of earth to get raw materials and building skyscrapers with the following words. "Think that, this mine is being dug out of the ground and planted on the surface" (Graham,2020, p. 292).

Graham reveals that there is evidence that transnational mining companies violated the following issues. These areas are human rights, labor, worker rights, and environmental justice.

What is the place and discussion of these violations between SDGs or other international treatise rules?

When we focus on gold mining companies Graham gives an important example from Laura Guitierrez Gomez. She studies violations of gold mining companies in Colombia and calls them "*Accumulated Forms of Criminal Applications".* This is because of the *"*state and company alliance" and this is "against and by harming systematically local's health, wealth and prosperity, they make their applications by dispossession" (Graham; 2020, p. 295).

Graham mentions the continuity of impacts for generations even after the mining companies left mining pit areas which he calls "*Sacrificed Areas".* The air, water, and land are contaminated and dirtied for years. Moreover, they can cause inherited poverty and diseases (Graham, 2020).

This reminds me of the study of Gill and Ritchie and the necessity of considering the cumulative social effects of technological hazards and disasters (Gill and Ritchie, 2020). As Scanlon, Johnston, and Sparling mentioned remains of accidents and impacts can be traced even 101 years after the Nova Scotia Mining Songs (2012). The generational transitions of effects of accidents can be prolonged.

Their impacts and memories can be carried in different ways even on discourses of music.

The Erzincan, İliç Gold Mine pit accident is a recent example from Türkiye. I have been working and observing hazards, and disasters in Turkey since the 1999 Marmara earthquake and am aware of recent developments in the region. On the 13th of February 2024, in the Çöpler area, İliç town of Erzincan province, a gold mine accident occurred. The earliest reason for this was labeled as sliding of soil and there were workers below it (AFAD, 2023). However, later on, that overloaded mining output of chemically sprayed and damped soil (Yığın Liç Alanı-Heap Leaching Field) erosion -2024 heavily in the area threatening the ecosystem. The main recent discussion topics related to this accident are the following who can trace what and how is the distribution of responsibilities? Who did what? Why are some companies protecting ecosystems in their own countries or locations but not care enough about bigger areas or other countries? A discussion is ongoing in Türkiye about this issue but there are obstacles. The Turkish Grand Assembly established a commission to observe developments after the disaster. Some of the lost and dead bodies of the workers and some of their vehicles under the slipped contaminated soil have gradually been found. There are accusations of bribery of the local people to accept the extension of the mining area and sell their lands, face forced migration and displacements occur. There are accusations of targetting, threatening even, or killing local activists, trade unionists, and NGO members in earlier times As Graham mentions (p. 294). But these issues require a detailed search and discussions which still are ongoing.

An example of mining meetings can be given from Canada. The yearly meetings of miners took place in Toronto, Canada in 2013. The local activist Nico Block's observations were important. There were two important meetings and Graham's summary of Block's observations. Canada Mining Search and Developers Union- PDAC has a yearly meeting of 30.000 delegates from 100 countries. At the same time, NGOs have meetings on Resistance of Locals Forced Displacement in isolated areas of three countries. Namely; Guatemala, Congo, and Mexico. Discussion topics of these meetings were burning villages, crises of environment and health, murdering activists and trade unionists, and mass threatening of women in mining areas with rape (Graham, 2020, p. 296).

These two meetings are valuable if one would like to make some changes for the future. I mentioned the importance of NGOs earlier in disasters (Öner, 2008) and collaborations of institutions and communities (Öner 2006; Öner 2024). According to the findings mentioned by Graham, the first international meeting seems powerful. Two reasons can be mentioned. Firstly because of the participants' diversity of countries. Secondly, a powerful conference coverage that has the power to be used if they wish to move hypothetically between local, national, and international findings from roots to grass or grass to roots (small, medium, and wider discussion levels) for better results, advice, and planning.

NGO's meeting is important and gives examples from three countries. If one wishes to communicate and create a partnership between two conferences. It seems that there was a chance at that time. NGO meetings can bring another stem of research from the field. If one would like to listen and communicate both there was an opportunity.

Both conference participants can interact and come up with proper results together. However, this usually does not occur. Discrimination of study groups and research areas often occurs, even if they take place at

the same time, and same location at the cost of study efforts, travel, and presentations. Scientific findings, discussions, and results are valuable for future planning and applications.

Cairncross and Kisting were examining platinum and gold mining in the Marikana Massacre 2016 in South Africa. They paid attention to communities with two mining areas by basing on findings of observations and interviews. They were questioning why mining itself is an extraordinary wealth source but why related workers and communities are not able to use its benefits. In one sense they reveal lakes of polluted water, waste rock, vast quantities of tailing dups, devastation of physical and social environment, occupational injuries, and diseases (such as silicosis), absent social security, disrupted rural and agricultural communities, and co-morbidities (Cairncross and Kisting, 2016).

Gough (2019) gives an example of Ghanaian experience in three gold mining settlements. They explore out and in migrations, who builds houses, attachments, socio-temporality, and gender-selective workers. They reveal the heterogeneity of settlements. Communities require proper settlements but they are linked to the time of mine operations.

Velez-Torrez, *et al.* (2018) evaluate "Mercury Pollution and Artisanal Gold Mining in Alto Cauca, Colombia: Woman's Perception of Health and Environmental Impacts". They reveal the necessity of a transdisciplinary approach to studying this subject. They develop a platform-closed-loop integration of social action and analytical chemistry research by focusing on especially women in the area.

Besides this Marston and Perreault exemplify mining cooperatives and resource regimes in Bolivia. As they call the country is experiencing a boom in resource extraction. Ther refers to consent, coercion, and cooperatives by referring to Gramsci's concept of hegemony and the integral state, particularly in the Oururo and Potosi departments. They trace the relationship between mining cooperatives, mineral, water, and territorial governance. They conclude that there has been a close historical relationship between mining cooperatives and the Bolivian state since the 1930s.

The complexity of the study area brings many examples forward from the literature. Once the analysis is complete after a classification, wider discussions will be forthcoming.

Conclusion

Instead of a conclusion, I would like to call for a beginning with questions, the necessity of doing more studies on this area, and an increase of awareness of what is going on in the field not only on the papers.

- Who is responsible for mining processes?
- What are agreements and how much is observed in the frame?
- Is there any ecological crime in the process?
- Why are army and policing facing locals and protecting companies?
- How can the cost of mining disasters be measured?
- What are the short, medium, and long-term results?
- Who and how much is responsible for taking related measures?
- Why accumulated chemical soil is overloaded?
- What is the proportion of poisoning of water, soil, and air?

- Do they have the right to poison them?
- Who and which sources will be used to clean and rehabilitate them?
- Why mining actors do not observe after their violent actions and do promised rehabilitations in the environment and ecosystem?
- Under these conditions How can sustainability goals be monitored in wider perspectives?
- How can we achieve justice, equity, and equal distribution of resources and observe rights properly?

Acknowledgement

This paper is based on a presentation at the ISDRS' 30th Congress and is devoted to people and ecosystem affected by mining activities.

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9c. Participation and the Role of Stakeholders

Submission ID: 176

Pursuing Good Governance through Participatory Budgeting: Some Insights from Concrete Experiences in European Municipalities

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Abstract

International institutions involved in economic development emphasized the importance of governance in the public sector (Woods, 2000). Indeed, since 1989, the World Bank has established a framework for 'good' governance (GG) (Lateef, 2016). This concept was also explicitly noted by the International Monetary Fund, which based the definition on "the transparency of government accounts, the effectiveness of public resource management, and the stability and transparency of the economic and regulatory environment for private sector activity" (IMF, 1997). In addition, the OECD (2007) defined GG as follows: "Good governance is characterized by participation, transparency, accountability, rule of law, effectiveness, equity." From its beginnings, GG relates to democracy, community participation, accountability, efficiency, and responsiveness (Kim *et al.*, 2005). In particular, the link between participation and democracy (Michels, 2012) appears as a critical factor since participation is necessary for democracy (Boyte, 2005). Thus, citizen involvement has emerged as a central feature of a 'new' type of GG (Blomgren *et al.*, 2005). Discussions about GG have also extended to the level of local government (Lawton & Macaulay, 2014), further highlighting the link between governments and citizens and emphasizing the concepts of participation, democracy, engagement, transparency, and trust (Denters *et al.*, 2016). Community involvement is achievable through participatory governance and budgeting, which emerges when public institutions apply interactive political leadership (Sørensen & Torfing, 2019), involving the community in policymaking (Edwards, 2001). This work will analyze the possible role of participatory budgeting (PB) in developing the founding principles of GG in local governments. The work develops a framework for analyzing the characteristic features of GG through an analysis of the fundamental documents on this topic provided by international institutions and a literature review in public management studies. Consequently, the work applies a qualitative research methodology based on research interviews with public officials and local politicians directly involved in PB practices. The research interviews have been processed through a content analysis conducted following the approach developed by Gioia *et al.* (2013). The characteristic features of GG were structured into sublevels and discussed for consensus, following the recommendations of Vaismoradi *et al.* (2013). The author used a specific software for coding, and the texts of the research interviews were analyzed line by line and word by word. The research is currently ongoing. About its expected results, on the one hand, this work will lead to the definition of a framework of the characteristic features of GG applicable at the local level. On the other hand, based on already consolidated PB experiences, the research will offer initial results of an exploratory nature on the ability of PB processes to encourage the development of the constitutive principles of GG at the local government level. SDG+Target: 16.6; 16.7; 16.10; 17.17. This contribution relates to the topic of the Conference because it analyzes the potential of participatory budgeting to foster greater awareness of local communities in participating in governmental decision-making mechanisms, encouraging the promotion of new development strategies for environmental and social sustainability at the local level.

Submission ID: 284

Governance of Regeneration in Mining Post-Disaster Communities: A Critical Analysis of Brumadinho, Brazil

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Abstract

This study endeavors to conduct a comprehensive analysis of governance dynamics involved in the post-disaster reparation of Brumadinho, Brazil, following the catastrophic collapse of Vale S.A.'s tailings dam on January 25, 2019. Recognized as the largest workplace disaster in Brazil's history, this event resulted in 272 fatalities and had profound socio-environmental and economic consequences. The selected case study stands out for the extensive involvement of actors from civil society, the State, and the market, shaping policies and programs for the reconstruction of the affected territory. This complex landscape has given rise to a nuanced interplay of disputes, conflicts, partnerships, and risks, influencing governance and sustainability in Brumadinho. The term "Reparation Governance" serves as a conceptual framework, guiding the understanding of diverse practices and interrelations among civil society, the private sector (including Vale and its subcontractors for reparation actions), and the State (encompassing municipal, state, and federal authorities, as well as the Public Ministry). While there is a scarcity of literature explicitly employing the term "Reparation Governance," the study highlights the need to consider governance and reparation elements in the post-disaster context. The research problem addresses the critical examination of corporate responsibility practices and Translocal Governance dynamics, focusing on the power dynamics of multinational extractive companies. Translocal Governance, prioritizing the well-being of marginalized communities, emerges as an alternative model challenging the dominance of such corporations. The study aims to fill a gap in the literature by providing empirical data on local governance patterns, analyzing political dynamics, and scrutinizing concrete policies. To address the central research question – "How is the proposed governance model for the post-disaster scenario promoting the reparation of Brumadinho's territory?" – the study adopts a triangulation of research methods. This approach seeks to offer a comprehensive analysis of the effectiveness of the proposed model, popular participation, and perspectives for improvement. Anticipated results include insights into the ongoing model's efficacy, discussions on popular participation, and the formulation of new study agendas to enhance future governance and reparation practices. This research, conducted precisely five years after the disaster, serves as a critical reflection on the state of reparation efforts, addressing challenges highlighted in previous literature. By exploring Brumadinho's governance structure and associated challenges, the study contributes to a deeper understanding of the complexities involved in post-disaster reconstruction, providing valuable insights for policymakers, stakeholders, and researchers. The ultimate goal is to promote a more resilient and effective approach to reparation governance in the aftermath of socio-environmental disasters, ensuring a sustainable and equitable recovery process for affected communities.

Posters

Submission ID: 187

Sustainable Nature Resources Governance: Stakeholders and Participatory Communication Framework

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Abstract

Dviete river region and Lubana lake region in Latvia as two cases of water resources management territories chosen have undergone comprehensive governance studies process. Case Study Research methodology was applied by approaching the study area as a socio-ecological territorial and human system, using in-depth semi-structured interviews (38) and express-interviews (61) in the region with all main local-regional and national stakeholder groups, including also experts, in addition to related document studies and territorial/objects' observations. Sustainable water resources governance developments are still being partially limited by **not** sufficiently developed cross-sectorial understanding and its legal, planning, communication and top-down management applications, as it is to be seen also during evaluation of two Natura 2000 framed territorial watershed case studies research applications in Latvia, which to some extent are characterizing general situation in the country, also in the field of nature protection management. From other side, as a kind of partially compensatory mechanism**,** there is to be recognized local bottom-up management applications**,** as real institutional instruments developing eventually more cross-sectorial understanding and practice at the local level, as well as, importantly having innovative participatory management qualities. In the conditions of limited national management level support, local municipalities, having not enough administration capacities, are developing different specific management approaches being without locally present nature protection administration personal. This approach could be called as non-governmental management approach. However, NGO partnerships with municipalities are still important, particularly, in the lake/nature infrastructure maintaining and development etc. as in the studied case of Dviete River Valley NGO. Another approach could be recognized and called as tourism communication management approach**,** in general comparison, being formally similar to the widely known traditional municipalities owned Tourism Information Centers. But in case of Lubana Wetland Information Centre, such institution is managing not only nature and tourism information, but also education/training and pro-nature behavior activities, even participatory works, so covering whole complementary set of nature-environmental communication instrument groups**.** Also, as Lubana lake and the whole Lubana Wetland Natura 2000 territory have no locally present nature administration, Lubana Wetland Information Centre is partially performing their duties too, especially, in information and consultation etc., what all can and shall be further developed in partnership between national Nature Protection Agency and municipality, and, in collaboration with other stakeholders. Mentioned examples of specific bottom-up management approaches, actually recognize that either local municipalities related NGOs, nature tourism and also nature communication institutions could be assigned as really important sustainable water resources and nature protection management institutional instruments and often as the only one institutional instrument locally available. In the case of Lubana lake and wetland management, tourism should be emphasized not only as a management sector, but also as an important instrument for nature/lake protection and factor to stimulate the development of other local sectors. All diverse sectorial and general stakeholder interests are to be communicated, coordinated and collaboratively governed, and, in particular, during all the stages of governance process (assessment, policy and planning, management, monitoring and communication), what's often is still not fully realized in practice.

9d. Legal Aspects of Sustainable Development

Abstracts

Submission ID: 194

Nature as a Stakeholder: How to Give a Voice to Nature in Corporate Stakeholder Engagement Processes as Required by the EU Corporate Sustainability Reporting Directive?

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Abstract

This paper analyses the role of Nature as a stakeholder in corporate best practices and identifies various ways in which Nature can participate in the corporate governance structures. The EU Corporate Sustainability Reporting Directive (CSRD) requires in the articles 19a and 29a that companies and groups should report on how their 'business model and strategy take account of the interests of [their] stakeholders'.*(*https://eur-lex.europa.eu/legalcontent/EN/TXT/*?toc=OJ%3AL%3A2022%3A322%3ATOC&uri=uriserv%3AOJ.L_.2022.322.01.0015.01.ENG)*

As set out in multiple reports, among others, by the Taskforce on Nature-related Financial Disclosures *(https://tnfd.global/)* and the WWF Living Planet Reports *(https://www.wwf.nl/wat-we-doen/focus/biodiversiteit/living-planet-report)*, corporate activities impact the state of Nature everywhere in the world. The Planetary Boundaries studies of the Stockholm Resilience Centre reveal that the planetary boundary of biosphere integrity has been transgressed substantively *(https://www.stockholmresilience.org/research/planetary-boundaries.html)*. The Planetary Boundaries indicate the boundaries for a safe operating space of humanity. Currently, 6 out of 9 boundaries have been transgressed: biosphere, freshwater change, land-system change, climate change, biochemical flows (phosphate and nitrogen), and novel entities. Besides the negative impact of loss of biodiversity and ecosystem services for human beings, the impact can also be considered from the perspective of the intrinsic value of flora and fauna. Although human beings are part of the community of life (Earth Charter, 2000), their economic and social activities have a great adverse impact on the non-human flora and fauna. Naess (Deep Ecology, 1987) approached environmental problems by looking for its roots deep in the structure of our western society and worldviews that guide it: "Ecological ideas won't save us, what we need is ecological identity, ecological self".

In the paper, as an attempt to amend such roots of the environmental problems, we propose to give Nature a voice in corporate governance structures to represent the interests of Nature in corporate decision-making. For our analysis, we conducted legal studies in several European jurisdictions (the Netherlands, Belgium, the United Kingdom, and Denmark) and the US and Canada to identify legal forms for giving Nature a voice. Additionally, by conducting qualitative research, we explored and categorized best practices by companies in said jurisdictions that have structurally included Nature as a stakeholder in their governance structures and/or decision-making processes. Based on the findings of both studies, we developed a taxonomy for innovative Nature-inclusive governance models, which is presented in this paper. This taxonomy is supported by a toolkit for other companies that intend to give Nature a voice as stakeholder. This paper supports SDGs 14, 15 and 16.

Submission ID: 195

Rights of Nature in the Constitution or National Law: How to Give a Voice to Nature in Our Society?

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Abstract

This paper analyses and compares initiatives to grant rights to Nature in the constitution or national law. The paper covers various countries in the Americas, Europe Africa and Asia.

As set out in multiple reports, among others, by WWF Living Planet Reports *(https://www.wwf.nl/wat-we-doen/focus/biodiversiteit/living-planet-report)*, human activities impact the state of Nature everywhere in the world. The Planetary Boundaries studies of the Stockholm Resilience Centre reveal that the planetary boundary of biosphere integrity has been transgressed substantively *(https://www.stockholmresilience.org/research/planetary-boundaries.html)*. The Planetary Boundaries indicate the boundaries for a safe operating space of humanity. Currently, 6 out of 9 boundaries have been transgressed: biosphere, freshwater change, land-system change, climate change, biochemical flows (phosphate and nitrogen), and novel entities.

Besides the negative impact of loss of biodiversity and ecosystem services for human beings, the impact can also be considered from the perspective of the intrinsic value of flora and fauna. Although human beings are part of the community of life (Earth Charter, 2000), their economic and social activities have a great adverse impact on the non-human flora and fauna. Naess (Deep Ecology, 1987) approached environmental problems by looking for its roots deep in the structure of our western society and worldviews that guide it: “Ecological ideas won’t save us, what we need is ecological identity, ecological self”.

In this paper, as an attempt to amend such roots, we examine and analyse how Nature can be given a voice in the public debate and in decision-making. For our analysis, we compared initiatives to grant rights to Nature in the constitution or national law. The paper covers initiatives and laws in Ecuador, Bolivia, El Salvador, Chili, Sweden, Finland, Ireland, Italy, France, Switzerland, Germany, the Netherlands, Uganda, the Navajo Nation, Aruba, Panama, and Bhutan. The text of the laws and legislative proposals are compared. Special attention is given to the wording or description of Nature in those initiatives and laws.

Additionally, by conducting qualitative research, we explored and categorized the motivation for introducing such an innovative approach and we analysed in which way the initiative emerged, i.e. through a civil society initiative or another form?

Based on the findings of both studies, we developed a proposal for a Nature-inclusive constitution, which is presented in this paper. This proposal is supported by arguments supportive to be included in the Preamble. This innovative approach contributes to the Deep Ecology theory.

Key words: *Rights of Nature, Constitution, Innovative Legal Approach to Represent Nature, Nature, Environment.*

Submission ID: 241

Right to be Free from Water Pollution in Malaysia: An Analysis on the Legal Aspects

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Abstract

The availability of clean water has been a constant issue in Malaysia based on frequent unscheduled water disruptions due to industrial pollution. The severity of this issue causes not only economic loss but also causes health issues for affected victims. This continues even though many agencies are equipped with laws to control and prevent pollution. This research intends to address the legal issue in controlling industrial pollution, in particular how laws protect the right of a citizen to be free from pollution based on doctrinal analyses of legislations and case laws. The researchers found that 1) the Malaysian Federal Constitution which is the local equivalent of the UK's Bill of Rights, and the supreme law of the Federation guarantees nine (Articles 5 – 13) fundamental rights. However, a one court ruling in this regard is inadequate to uphold the right to be free from water pollution in the absence of such express provision in the Federal Constitution. 2) Although international principles and practices are not automatically binding in the absence of domesticating it into the nation's context in Malaysia, major steps have been taken to ensure clean water and sanitation. This includes the 2005 constitutional amendment that allows the federal government to transform the water services sector, incorporating SDG 6 in the 12th Malaysia Plan (12MP), and the Water Sector Transformation (WST 2040). Nevertheless, the federal-state conflict remains an impediment to improve the water sector. 3) the relevant legal framework remains sectoral and has not been integrated in ensuring target 6.3 of SDG 6. Hence, there is no integration to improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and increasing water recycling. The discourse on human rights aspects of SDG6 will enhance the debate on environmental justice under SDG16 and the importance of public-private- partnership under SDG17.

Submission ID: 267

Evaluation of SDGs and New Agenda: New ISDRS Series Proposal

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Abstract

Presentation of a new ISDRS initiative to initiate a new publishing series on evaluation of 17 SDGs as a part of global discussion on new Agenda 2030.

The project will include writing 17 short manuscripts but also creating a platform that will invite researchers from around the world, build contacts with UN, promote the results, and maybe eventually join the process of writing the New SD Agenda.

The project would include (suggestion):

1. Creating the series editors' group
2. Creating 17 interdisciplinary groups. Each group should include at least a lawyer, experts on certain SDGs, experts which help prepare and evaluate the questioner.
3. Preparing methodology which will include:
   - analysis of legal acts and literature to identify the areas of SDG implementation (good and bad practices) where we can observe the success and failure, and
   - based on literature and legal act it will be prepared questionnaire for researchers and professionals dealing with certain SDG to consult which areas, actions, are in their opinion the most successful and the biggest failure to compare some "unpublished knowledge" with the literature results and based on them prepare the final suggestions.
4. Cooperation with the UN, UNU and other leading organizations working on SDGs. ISDRS might invite as authors leading professors from certain areas, whose role will be also to involve their communities and contacts into the consultation process to make questionnaires spread and promote the entire process.
5. Special Tract during ISDRS Conference in 2025 or 2026.
6. Funding applications.
7. 17 published short manuscripts (around 70-100 pages each).

The Track 9D, Governance, power and institution - Legal aspects of sustainable development can play leading role in this process.

Submission ID: 277

Legal Aspects in the Management of Healthcare Waste in Brazil: Home Care Modality

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Abstract

Home health care, also called home care, is a treatment used when the doctor recommends or allows the patient to receive health care in their home or residence. It covers health actions that can be carried out at home and by a multidisciplinary team aimed at promoting, maintaining and rehabilitating the patient. Such actions involve medical, housing, sanitation policies, among others, and generate the production of health service waste (HSW), that is, waste from health care that requires prior treatment for final disposal. The management of waste produced within the scope of home care must comply with specific legislation for the case, meeting the objective of sustainable development to ensure responsible production and consumption standards. The management, involving the segregation, conditioning, storage, collection, transportation, treatment and final disposal of health waste is provided by several specific laws and technical standards, with Conama Resolution nº 358, of April 29, 2005, being the main one, classifying health service waste into 5 groups: I - Group A, waste with the possible presence of biological agents; II - Group B, waste containing chemical substances; III - Group C, materials that contain radionuclides; IV - Group D, waste that does not present a biological, chemical or radiological risk to health or the environment; V - Group E, sharp materials and all broken glass utensils in the laboratory and other similar items. Specifically for home care, the specific standards of the National Health Surveillance Agency (ANVISA), which also supervises the home care system, apply. The Resolution of the Collegiate Board of Directors (RDC) No. 222, of March 22, 2018, provides for the Technical Regulation for the management of waste from healthcare services. Therefore, the objective of the present study is to verify how the management (segregation, packaging, identification, transportation and final disposal) of healthcare waste occurs in the context of home care, aiming to exclude or minimize risks to the environment. Despite the standards prescribed in the cited in the RDC, the process is much more complex, requiring knowledge of other precepts found in various referenced resolutions and technical standards (NBR). The multidisciplinary team and the patient are also part of the management and, if they do not manage waste correctly, they may dispose of it incorrectly, bringing risks to people and the environment in which they live. When analyzing the management of health waste produced by home health care, inadequacies are observed due to the lack of regulatory knowledge; preparation of those living in the residence, as well as the home team; absence of physical structure in residences for temporary storage and safe transportation to the final destination. Regulatory restructuring and simplification, training of people who will care for the patient and who live at home, as well as an easily accessible public policy for the disposal of small-volume infectious materials, are necessary to preserve the health of the population and the environment. It is essential to practice humanized medicine with better quality for the patient, ensuring sustainable development, meeting responsible consumption and production standards.

Submission ID: 280

Navigating Ecoanxiety: Exploring the Interplay between Climate Change Laws, Mental Health and, Sustainable Development Goals

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Abstract

This paper delves into the intricate relationship between climate change laws, Mental Health and the Sustainable Development Goals (SDGs), shedding light on the psychological implications of legislative responses to the climate crisis within the framework of sustainable development. Drawing upon interdisciplinary research in environmental psychology, policy analysis, public health, and sustainable development, this study examines how climate change laws influence individuals' perceptions, emotions, and coping mechanisms in the face of environmental uncertainty, while also contributing to the achievement of SDG 13 (Climate Action), SDG 3 (Good Health and Well-being), and SDG 17 (Partnerships for the Goals). The article explores five key relations between climate change laws, ecoanxiety, and the SDGs, including the impact of legislative response on public perception, the role of policy uncertainty in exacerbating anxiety, and the differential effects of climate policies on vulnerable communities. Moreover, the goal is to evaluate the trends and current stage of laws and ecoanxiety around the world and in Brazil, as it is or it is not generating ways to alleviate ecoanxiety within the context of climate governance and sustainable development. This article provides insights into the complex dynamics shaping psychological impacts concerning climate change and climate change laws, specifically on the field of ecoanxiety.

Full Papers

Submission ID: 254

The Social Function of the Basic Sanitation Contract as an Instrument of Sustainable Development in Brazil

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Abstract

The right to basic sanitation is a social right that depends on the state providing services to make it effective. To propose a public policy, in any sector, it is necessary to build norms, processes and institutional arrangements mediated by the law, which is considered an intrinsic element in the development of such policies. The legal framework for basic sanitation, structured by Law No. 11.445 of January 5, 2007, as well as the changes promoted by Law No. 14.026 of July 15, 2015, proves numerous public policies that go beyond the obligation to universalize water supply and sanitation to guarantee sustainable development. Thus, the aim of this study is to analyze the administrative contract, in compliance with its social function, as an instrument for promoting sustainable development in the basic sanitation sector.

Keywords: *Public Policies. Basic Sanitation. Social Rights. Universalization. Public contracts.*

Introcution

According to data from the United Nations (UN, 2023), around 46% of the global population lives without access to basic sanitation, i.e., on a planet with eight billion people, 3.6 billion do not have safe basic sanitation services.

The reality of the basic sanitation sector in Brazil is no different and reflects neglect, a lack of political will and little investment in the sector. According to data from the National Sanitation Information System (SNIS), for the year 2021, more than 15% of the population had no access to water supply services, which corresponds, in absolute numbers, to more than 36 million people without access to this public service and more than 50% do not have a sewage service, which corresponds to more than 94 million people who do not have access to a public sewage service.

In view of the deficient situation and the urgent need to rearrange the sanitation sector in order to meet the objectives of sustainable development, a reconfiguration of the normative aspects of the sector was promoted in order to guarantee universal access to drinking water and sewage to the entire population, structured in Law No. 11.445 of January 5, 2007 and in the amendments promoted by Law No. 14.026 of July 15, 2015, which became known as the legal framework for basic sanitation.

The legislator included public policies in the legislation that corroborate the universalization of drinking water supply and sewage disposal and enhance the fulfillment of the fundamental and social rights provided for in the Constitution of the Republic and are among the goals of the United Nations 2030 Agenda, in particular goal n. 6 (access to drinking water and sewage disposal) and n. 10 (reduction of inequalities).

It is important to point out that the regulation of the basic sanitation sector brings together the private sector as a means of implementing public policies to universalize the service, with the aim of investing more than the public resources already earmarked for the sector. To this end, the concession contract plays a leading role, after prior bidding and broad competition, for the provision of water supply and sewage services.

Aim of the study: To analyze the public contract as an instrument for implementing the public policies included in the infra-constitutional legislation on basic sanitation, which cooperate to achieve the goal of universal access to drinking water and sewage. To this end, a brief analysis will be made of the concept of public policies and their intersection with the basic sanitation sector. Subsequently, a brief survey will be made of the public policies listed in the sanitation legal framework and, finally, the possibility of using the public contract as an instrument of implementation will be analyzed.

Literature View

The Sustainable Development Goals are a global call to action to end poverty, protect the environment and climate, and ensure that people everywhere can enjoy peace and prosperity (UN, 2023).

Faced with the global scenario that has led to the structuring of the United Nations' 2030 Agenda, there is an urgent call for states to include public policies aimed at sustainable development on their government agendas to guarantee a balanced environment for present and future generations.

In this sense and considering that one of the objectives of sustainable development is No. 06, which aims to "guarantee the availability and sustainable management of water and basic sanitation for all", this article aims to analyze the use of administrative contracts in the sanitation sector as a means of making fundamental and social rights effective.

The Constitution of the Federative Republic of Brazil, in Title VIII - The Social Order, specifically in article 193, sole paragraph, states that the "State will exercise the function of planning social policies, ensuring, in the form of the law, the participation of society in the processes of formulation, monitoring, control and evaluation of these policies".

The sole paragraph was included in the constitutional text on August 26, 2020, through Constitutional Amendment n. 108, which denotes the legislator's concern to bring the legal system closer to the structuring of public policies, avoiding a dissonance between the abstract letter of the law and the factual reality of the needs of the community.

Although the constitutional commandment is a "must be" *in the abstract,* the legal norms are tainted by pressure from the interests of both private and public agents. Thus, according to Maria Paula Dallari Bucci (2021, p. 35) "the challenge ahead is to develop legal forms and regimes that give public policies greater consistency, expanding their scope and quality, with maximum use of scarce resources".

For Diogo Rosenthal Coutinho (p.21) "the law cannot only be understood as a set of means by which the ultimate objectives of public policies are achieved, but also as internal rules that allow the calibration and operational self-correction of these same policies".

According to Irene Guimarâes Altafin (2023, p.39), the regulatory restructuring of the basic sanitation sector in Brazil with the aim of achieving the goal of universalizing water supply and sanitation for the entire population took place after cycles of implementing public policies that "alternate with long periods of institutional voids and discontinuity of investments, impacted by the macroeconomic and political scenarios". Since 2007, Brazil has had a legal framework with Law 11.445/2007, which provides for national guidelines for basic sanitation.

The author Thiago Lima Breus (2019, p.173) presents the public contract as an instrument for implementing public policies: "(...) in which the public administrative contract assumes an effectively leading role in the exercise of government activity". And he continues: "as it is based on the premise of the scarcity of financial resources, the realization of public policies can be carried out through public procurement, which makes it possible to circumvent the direct use of public resources for the implementation of public policies, with the consequent satisfaction of fundamental rights" (2016, p. 187). In this way, public contracts can be an instrument for implementing public policies, especially in the basic sanitation sector. However, it is of the utmost importance that the Public Authority, the contracting party, acts to supervise the contracts, in this case imposing its power of empire so that the contractor serves the population through social policies proved in the contractual clauses.

Methology

In order to carry out the research and solve the proposed problem, a documental study was used through bibliographic research, and in order to obtain data on the basic sanitation sector, research was carried out with the databases of the Institute of Applied Economic Research - IPEA; the Program for Strengthening Institutional Capacity for Management in Regulation; the National Sanitation Information System - SNIS. To analyze public contracts as an instrument for achieving basic sanitation public policies, laws and regulations were analyzed, as well as contracts signed after the publication of the basic sanitation legal framework, with the aim of verifying the inclusion of cross-cutting public policies in addition to the central content of the contract.

Results and Discussion

The Constitution of the Republic of 1988, in Title VIII - The Social Order, specifically in article 193, sole paragraph, states that the "State will exercise the function of planning social policies, ensuring, in the form of the law, the participation of society in the processes of formulation, monitoring, control and evaluation of these policies". Therefore, there is an express constitutional order for the state, through government actions, to give effect to the fundamental and social rights set out in the constitutional text.

A relationship has therefore been established between government, politics and law, which, according to Maria Paula Dallari Bucci (2021, p. 34), is the legal element that connects them, which brings legitimacy to state action by providing rights that are effectively accessible and capable of reducing inequalities, ensuring that every person can be fully integrated into society". As Diego R. Coutinho states (p.16), the Law intensely permeates public policies in all their phases or cycles: in the identification of the problem (which may itself be a legal bottleneck), in the definition of the agenda to tackle it, in the design of proposals, in the implementation of actions and in the analysis and evaluation of programs.

Public policies serve as a link between the legal description of a social right, in other words, a means of achieving the public interest. According to Subirats, Knoepfel; Larrue; Varone (2008, p.35) the term public policy was introduced in the 1970s as a literal translation of the term *public policy* and was defined as: a series of intentionally coherent decisions or actions taken by different actors, both public and sometimes non-public, whose resources, institutional links and interests vary, to solve a problem that is politically defined as collective. This set of decisions and actions gives rise to formal acts, with a varying degree of obligation, aimed at modifying the conduct of social groups that are supposed to have originated the collective problem to be solved, in the interests of social groups that suffer the negative effects of the problem in question. The authors start from the premise of the need to solve a social problem by explaining the processes, procedures and resources needed to achieve the goal through a legal set of rules that guarantee the structuring of the actions of the Public Authorities.

Among other definitions of public policy compiled in the literature on the subject, one can cite Thomas Dye (1972, *apud* Howlett; Ramesh. Perl, 2013, p.26), who offers a simplistic view of public policy, defining it as "everything the government decides to do or not to do", this decision being made by elected politicians or other official officials.

Maria Paula Dallari Bucci (2021, p. 53), in turn, defines public policy as: "a government program or framework, because it consists of a set of articulated (coordinated) measures, whose scope is to give impetus, that is, movement to the government machine, in order to achieve some public order objective, or in the view of jurists, to realize a right", denoting that public policy depends on government action, that is, the structuring of competences, objectives and state means that make up the government machine.

Thus, on an ideal and abstract level, the purpose of public policy is to achieve defined aims, translated into the identification of problems to be included on the government agenda, which are necessary to achieve the result, i.e., the solution to the social problem.

As Fábio Konder Comparato (2023, p.45) states, public policy is an "organized set of rules and acts aimed at achieving a specific objective", in other words, it is a strategy for solving public problems.

It is a "construction of the data of experiences from theoretical and evaluative perspectives" (Villanueva, 2006, p. 46), structuring itself "through legal norms and legal acts, in other words, the DNA of public policies is written in legal codes" (Sundfeld; Rosilho, 2014, p.48).

A policy is public when it contemplates public interests, that is, the interests of the community - not as a formula justifying differentiated care for interests or the undifferentiated neglect of interests that deserve protection - but as a realization desired by society. But a public policy must also be the expression of a public process, in the sense of being open to the participation of all interested parties, direct and indirect, so that the positions at stake can be clearly and transparently expressed (Bucci, 2021, p. 39).

Therefore, the implementation of public policies consists of the ability to realize the consequences foreseen after the initial conditions, if the administrative choices have been fulfilled, in other words, the

realization of the public policy described in the law depends on the governmental actions of choice and planning having been conducted.

By formalizing a political decision (...) in the form of a government action program, the law adds cogent features (i.e., binding, not optional) to it, distinguishing it from a mere intention, recommendation or proposal for action whose adoption is optional. (...) The law gives public policy its official character, dressing it in formality and crystallizing its goals which translate clashes of interests through a solemnity of its own (Coutinho, p. 19).

Based on these considerations about public policies and law, we will analyze the public policies included in the Brazilian legal system in the basic sanitation sector, with a period of the publication of the legal framework for basic sanitation in 2007 and its amendment in 2020.

The Restructuring of the Basic Sanitation Sector and Public Policies

The structuring of basic sanitation in Brazil occurred through a trajectory marked by cycles of implementation of public policies that "alternated with long periods of institutional voids and discontinuity of investments, impacted by macroeconomic and political scenarios" (Altafin, 2023, p. 39).

It was only in 2007 that the restructuring of basic sanitation came to a head, when Law 11.445/2007 was passed in January, setting up national guidelines for basic sanitation, and becoming known as the legal framework for basic sanitation. Brazil now has a framework for the sanitation sector (...) encompassing water supply, sewage disposal, solid waste collection and disposal and urban rainwater drainage (Altafin, 2023, p. 44).

The basic sanitation framework brought in the National Sanitation Plan - PLANSAB as the main instrument guiding public policies at the federal level. Its function is to identify and prioritize actions, linked at the federal level to the Union's General Budget and the Multi-Year Action Plan (PPA).

PLANSAB, approved by Decree No. 8,141 of November 20, 2013 and Interministerial Ordinance No. 571 of December 5, 2013, set targets of 99% of urban and rural households supplied by a distribution network or by a well or spring with internal plumbing by 2033; 92% of urban or rural households served by a sewage collection network or septic tank; and 93% treatment of collected sewage. To meet the targets, set, investments in the order of R$500 billion, or R$16 billion per year, have been estimated for basic sanitation interventions.

Although Law No. 11.445/2007 has brought important advances to the sector, expanding access to water supply and sanitation, and also including other public policies that corroborate goal No. 6 of the United Nations 2030 Agenda, as shown in Table 1 - Public Policies in Law No. 11.445/2007, in 2019, according to data from the National Sanitation Information System (SNIS, 2023), more than 15% of the population still had no access to water supply services. As for sewage services, more than 90 million people had no access to sewage.

These figures are the result of countless discontinuous and insufficient investments, with low effectiveness of sanitation investments and low technical efficiency of services, slowness in drawing up

municipal plans, irregular program contracts with no clear targets, lack of standards and guidelines for regulation, among other situations that have led to a new regulatory restructuring of the sector.

Thus, on July 15, 2020, Law No. 14.026/2020, known as the new legal framework for basic sanitation, was published, which brought changes to the sanitation sector, amending several provisions of Law No. 11.445/2007.

In this way, it is up to the public manager to find ways to implement the provisions of the law, because public policies are in constant flux, whether they are being adapted, adjusted or evaluated, which is why it is important to have a minimally flexible framework, so that adaptations or revisions can be made to the construction of public policy and thus ensure accountability to the democratic system's control bodies.

It should not be forgotten that legal norms arise from the pressure of interests, i.e., the bodies responsible for issuing norms are veritable arenas in which the interests of both private and public agents are present and legitimately look to be accepted by legislation. And it is these interests that give rise to the rules and are reflected between the lines of the legislation (Sundfeld e Rosilho, 2014, p.57).

As an example, in the basic sanitation sector: one of the measures introduced by Law 14.026/2020 to achieve the goal of universal access to water and sewage for the entire population is the "forced" regionalization of services, aimed at attracting private investment.

If previously the role of entrepreneur providing the service was reserved for the states, the new legal framework for sanitation requires them to dress as legitimate public managers. This change is in line with the ban on the provision of services through program contracts, signed between states and municipalities without prior bidding, putting an end to the model that guaranteed state companies dominance in the sector (Guzela, 2022, p. 168).

The law brings as a benefit to the entities that structure themselves in a regionalized way, easier access to the resources made available by the Union, that is, the new legal framework for basic sanitation has made the allocation of Union resources conditional on the structuring of regionalized provision.

The authors Silva; Feitosa and Soares (2021, p. 10) understand that the regionalization of basic sanitation services denounces "the risks of false development policies, the benefits of which end up being concentrated in the hands of small international and domestic groups", whereby the strategic objectives of peripheral public policies will not have fulfilled their purpose, meaning that the most vulnerable population will remain on the margins of public service provision.

Therefore, the challenge facing public administration today is to develop legal forms and regimes that support public policies, expanding their scope and quality, with maximum use of scarce resources. It means balancing a triangle between governance, the capacity to implement public policies and democratic control, even by the population (Bucci, 2021, p. 35).

To build a balance and reach the entire population, the Public Administration needs to innovate, seeking different possibilities for the legal modeling of public policies. The choice of the most right administrative

law instruments and the design of induction or reward mechanisms for certain behaviors (...) are examples of topics that arise when the law is instrumentalized by a given action strategy. The law would be what Coutinho (n.d. p.21) metaphorically called a "toolbox, which performs middle tasks connected to certain ends in a more or less effective way (...)".

In a developing society such as Brazil, government innovation in the structuring of public basic sanitation policies depends not only on innovations as such, but also, to a large extent, on the combination of these incremental improvements, the results of which create conditions for social legitimization and, with this, permanence and positive feedback on this process.

The development agenda is opening to an understanding of how public policies are formulated and implemented, through different arrangements, whether for the direct provision of rights, or for the organization of the economic and social forms that are related to this result, based on initiatives directed and coordinated by the public authorities. The improvement and modernization of public services and infrastructure (...) as well as social inclusion policies and all long-term initiatives depend not only on an understanding of the roles of the state and government, but also on technical mastery of their operating mechanisms (...) (Bucci, 2021, p.49). (emphasis added)

When making administrative choices by the needs of the community, public managers need to go beyond the provisions of the law. To improve and modernize public services and to insert social inclusion policies, the Public Administration needs to look for other traditional legal means of structuring public policies, and can use new forms of legal structuring, such as public contracts.

The Public Contract as a Means of Realizing Public Policies

The state's contractual activity can no longer be understood as a mere instrument for meeting administrative needs. It needs to be reorganized so that it also satisfies constitutional rights and freedoms.

Public procurement translates into new ways for the state to develop public purposes that, until then, would have been carried out by other traditional means of state action which, in turn, would have been the responsibility of the Public Administration to carry out, allowing it to be concentrated on other specific sectors, with a view to the smooth running of the state (Valle, 2023, p. 21).

The public contract can therefore be used as a tool to promote the social and economic development of society. In this way, the public contract, the legal instrument that governs the relationship between the Public Administration and the company providing the basic sanitation service, assumes a social function in the construction of effective public policies for the sector.

There is talk of administration by contract "(...) in which the public administrative contract assumes a role of effective protagonist in the exercise of government activity" (Breus, 2019, p.173), so the manager can insert complementary public purposes to the central object of the contract, reflecting the choices dictated by public policies, giving effect to constitutional mandates.

This new perspective of contractualization by the Public Administration should be called the social function of the contract, opening space for the realization of social rights, whether with an economic, social or environmental bias, etc.

The social function in public contracts is an important instrument in protecting the public interest, as far as it inserts public policies aimed at realizing the fundamental and social rights of citizens, enhancing the production of favorable effects for a state administrative structure.

It is a principle of public order, giving impetus to a symbiosis between private and public law, since according to article 421 of the Brazilian Civil Code: "contractual freedom will be exercised within the limits of the social function of the contract" (Brazil, 2022), in other words, the autonomy of will be attenuated when meta-individual interests and individual interests relating to the dignity of the human person are present. The main characteristic of this principle is the limitation of contractual freedom, according to Statement no. 23 of the 1st Civil Law Conference.

However, the inclusion of social clauses in public contracts depends on the choices made by the Public Administration, as Sérgio Guerra (2021, p.41) states: The state is faced with the challenge of adopting modern and efficient management practices, which no longer see the administrative act as a simple realization of the state's choice, but instead seek categories, institutes and formulas that favor the mediation of conflicting, ambivalent interests, without losing sight of the fact that its function is eminently public.

To illustrate this scenario, we can cite the public concession contracts for basic sanitation services set out in Law No. 14.026/2020, which brought new wording to article 10 of Law No. 11.445/2007, providing for the mandatory signing of concession contracts, after prior bidding, for the provision of basic sanitation services: The provision of public basic sanitation services by an entity that is not part of the holder's administration depends on the signing of a concession contract, through a prior bidding process, under the terms of article 175 of the Federal Constitution, which cannot be governed by a program contract, agreement, partnership agreement or other instruments of a precarious nature (Brasil, 2020).

Specifically with regard to public basic sanitation services, it is clear that the legislator opted to delegate the provision of the service to private individuals under regulatory conditions and state control, since they include political, economic, legal and social elements in which the state must unequivocally be present, either regulating or controlling the rights and obligations of the providers, while guaranteeing and ensuring the rights of citizen users, in which a public service can become unviable (Aragão, 2013, p. 533).

Thus, like other administrative contracts, concession contracts are essentially adhesion contracts, "since it is the Public Administration that establishes the conditions of the deal in advance, and the winning bidder only expresses its agreement - its manifestation of will, in the face of the previously defined rules" (Oliveira, 2021, p. 107).

And the rules set out in Laws 8.897/1995 and 11.079/2004 apply to concession contracts, in addition to the specific sector legislation. Laws n. 14.133/2021 (Public Bidding and Contracts Law), n. 9.784/1999 (Federal Administrative Procedure Law) and n.12.529/2011 (Competition Defense Law) also apply in the alternative.

The legal provision of essential clauses in concession contracts is of the utmost importance for standardizing contractual instruments due to the principle of legal certainty. However, the public administrator, considering the different local realities of each federative entity, can insert specific clauses to meet the needs of the population, especially the most vulnerable.

The search for the best public interest legitimizes the delegation of public assistance policies to private initiative for the improved execution of public services. Given this premise, a new paradigm in contractual administrative activity has begun, aimed at increasing the quality and quantity of social public demand (Valle, 2023, p. 36).

To illustrate the insertion of social clauses as a new legal arrangement for implementing public policies in the basic sanitation sector through an administrative contract, we will analyze the concession contract signed by the state of Rio de Janeiro.

The draft concession contract for the state of Rio de Janeiro includes, in a timid manner, social policies (Rio de Janeiro, 2023). Item 1.1.5 only defines irregular, non-urbanized areas, previously defined by the Pereira Passos Urban Planning Institute, through SABREN - the Low-Income Settlement System, classified as slum areas and subnormal agglomerations, with the concessionaire being responsible for expanding the water supply and sewage system, which demonstrates the public administrator's concern with serving people in conditions of social vulnerability.

Item 11, dealing with non-urbanized irregular areas, proves that the concessionaire will manage providing services throughout the concession area of the block, including slum areas and subnormal settlements. In addition to the obligation to invest in irregular, non-urbanized areas, the concessionaire must also follow the provisions of Annex IV, known as the specifications, and be concerned with social issues.

Regarding the social tariff, according to article 44, paragraphs 8 and 9, of Law 11.445/2007, item 29.3 of the concession contract establishes the concessionaire's obligation to carry out the annual re-registration of beneficiaries in order for them to continue to be entitled to the social tariff, in addition to the calculation formulas and other mathematical methods for quantifying the social tariff.

Item 23.2.15 of the draft contract also deals with the issue of the social tariff, when dealing with users' obligations: to allow the concessionaire to enter their home or establishment so that it can promote the installation of domestic connections for properties in the subsidized residential category (social tariff).

In the words of Egon Bockmann Moreira (2022, p. 309), the tariff policy "in addition to representing an active policy for distributing wealth and enabling the concession to be financed, it is the tariff that defines which services will be provided, as well as which works will be carried out (and the respective amortization period)". It is up to the public entity, the holder of the public service, to define the tariff policy, because it is this policy that will fulfill the collective interest.

In this way, the administrative contract signed by the state of Rio de Janeiro with the private provider very timidly brought in public policies beyond those provided for in the sanitation legal framework, especially those aimed at the low-income population, with the obligation for the concessionaire to structure basic sanitation services in vulnerable areas, mechanisms for implementing the social tariff and socio-environmental programs aimed at environmental education, but nothing beyond what is already provided for in the sector's regulations.

The public administrator could justify the situation on the grounds of the cost of implementation, i.e., to conduct a public policy there is a need to weigh up the sacrifices in terms of efficiency and the aims to be achieved.

As it is based on the premise of scarce financial resources, the realization of public policies can be conducted through public procurement, which makesi t possible to circumvent the direct use of public resources for the implementation of public policies, with the consequent satisfaction of fundamental rights (Breus, 2016, p. 187).

It is important to clarify that the costs of implementing public policies, whether through compliance with the law or through a contractual clause, must be considered when drawing up budget instruments (Multi-Year Plan - PPA, Budget Guidelines Law - LDO and Annual Budget Law - LOA), as they are not "limited to the money that will circulate between users and the concessionaire but have repercussions on the structure of the entire operation of the concession project" (2022, p. 309).

This is what Garcia (2009, p. 37) calls the power of governance, which is based on a different argumentative rationality: attentive to factual details and the principles of law that they call for, weighing up interests, giving a voice to those who find it difficult to make themselves heard, adapting available means to ends, managing multiple actions with efficiency and prudence, constructing and reconstructing intentions with a permanent sense of the limitation that the law imposes on the actions that have to be carried out.

The success or failure of a public policy depends on the choice of the manager who will define, through the legal instruments available, the planning, execution and cost of their decisions. The interests of the state must be balanced with the cost to the private sector of conducting the service and the population, especially the most vulnerable, who often pay for the public service when it is not provided efficiently.

Concusion

The Public Administration seeks ways to make social rights effective, either by following public policies included in the constitutional text or through laws that hold a description of public policies to be implemented.

However, with the need to realize social rights combined with the goals of the United Nations' Agenda 2030 and considering the scarcity of public financial resources, public managers need to look for ways to develop administrative choices to meet the needs of the population.

Among the possible instruments for implementing public policies are public contracts, given the possibility of including social clauses, in addition to mandatory clauses, in their content, which makes it possible to fulfill the public interest.

In this way, administrative contracts should not be analyzed as an end in themselves, but as an instrument for conducting public policy. Considering the basic sanitation sector, with the legislative changes made by Law No. 14.026/2020, imposing the obligation of concession contracts in the provision of public drinking water supply and sewage services, it was possible to include social clauses, as seen in the contract signed by the state of Rio de Janeiro. We can consider this contract to be a small step forward in the possibility of using extra-legal support to implement public policies, showing the social function of the contract.

In this way, it is up to the Government to make the necessary considerations about the degree of need for the implementation of public policy, since the limitation of public resources is a limiting element in the realization of social rights. It is not enough to use new legal instruments, such as fulfilling the social function of the contract, but it is necessary to pay attention to public needs based on budget forecasts, so as not to burden the population, especially the most vulnerable.

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Additional Tables

Table 1: Public Policies in Law 11.445/2007

Device	Legal text
Art. 3b, sole paragraph, of Law 11.445/2007	In Special Zones of Social Interest (ZEIS) or other areas of the urban perimeter occupied by low-income populations, the public sanitary sewage service, conducted directly by the owner or by a concessionaire, **includes sanitary facilities for homes and a solution for disposing of effluents,** where. none exist, ensuring compatibility with the guidelines of the municipal land regularization policy.
Art. 11-A, § 3 of Law n. 11.445/2007	Compliance with the principle of **affordable tariffs for users and consumers** (...)
Art. 29, §2 of Law 11.445/2007	Tariff and non-tariff subsidies may be adopted for **users who do not have sufficient payment ability to cover the full cost of the services.**"
Art. 44, §8 of Law 11.445/2007	The service of connecting a building occupied by a low-income family to the sewage network may be **free of charge**, even if the public basic sanitation services are provided through a concession, seeing, when applicable, the economic and financial rebalancing of the contracts".
Art. 48, sole paragraph, of Law 11.445/2007	The Union's policies and actions for urban and regional development, housing, combating and eradicating poverty, environmental protection, health promotion, water resources and others of relevant social interest aimed at improving the quality of life must consider the necessary articulation, including about financing and governance, with basic sanitation".

Track 10 Special Themes

10a. ICT and Sustainable Transformation: Navigating SDGs

Abstracts

Submission ID: 9

Reshaping Business Strategy by Integrating Sustainability and Digitalization: A Literature Review and Research Pathways

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Abstract

Addressing the challenges related to sustainability and digitalization currently captures the attention of society, and particularly businesses. The continuous demands from stakeholders, coupled with the apparent link that both topics have with value creation and competitive advantage, have generated special interest among managers and academics. As a result, fields of study are beginning to consolidate with the purpose of conceptually and empirically understanding the implications that various factors related to sustainability and digitalization have on the business. Progress has been made in analyzing how both topics, their techniques, tools, practices, objectives, achieve points of convergence and synergistic development from a complementary perspective. Consequently, both critical factors (i.e., sustainability, digitalization) for the company's operation in the current context are intrinsically linked to the business strategy. In this context, our systematic literature review emerges, aiming to understand how the literature is accounting for the linkage between sustainability, digitalization, and business strategy. Two scientific contributions are made with the systematic literature review: (1) This study reveals how the interest in linking sustainability and digitalization influences and begins to shape central elements (e.G, organizational capabilities, organizational resources, business model, organizational performance, stakeholders, networks) that make up and deploy business strategy. (2) The challenges and paths that future research should address are discussed and proposed.

Keywords: *sustainability, corporate sustainability, digitalization, digital transformation, strategy, corporate strategy, business strategy, systematic literature review*

Submission ID: 202

The Implications of Artificial Intelligence on International Development Management

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Abstract

Artificial Intelligence (AI) has emerged as a powerful tool revolutionizing various sectors globally, including international development management. This research aims to explore the current landscape of AI implementation in global development management, assess the benefits and challenges associated with its adoption, and propose relevant policies and practices. A mixed research design, comprising qualitative and quantitative methods, was utilized to gather data from secondary sources. The qualitative section of the study draws upon case studies from diverse operational sectors to examine the impact of AI adoption. These case studies highlight how AI contributes to improved performance in various industries and the potential positive effects on individuals' lives. The quantitative part of the research utilizes data from renowned databases such as World Bank Open Data, United Nations Development Programme, International Monetary Fund (IMF), OECD Stat, and Global Open Data Index. Integrating qualitative and quantitative data allows for a comprehensive understanding of AI implementation's economic growth and development across different organizations worldwide. The findings reveal that AI adoption in international development management holds significant promise for enhancing organizational efficiency and individuals' well-being. However, the research also identifies various challenges associated with AI implementation, such as ethical considerations and potential job displacement. To address these issues, the study proposes policy recommendations and best practices that can guide organizations and policymakers in effectively harnessing the transformative potential of AI. This research contributes to international development management by providing a deep understanding of the importance of AI in the current context. The study offers insights for organizations adopting AI and assists policymakers in identifying and resolving pertinent challenges. By completing this study, organizations and policymakers can proactively address the existing problems and develop strategies to maximize the benefits of AI while minimizing potential risks. In summary, this research underscores the immense potential of AI in driving development and improving lives, laying a foundation for future advancements in international development management.

Keywords: *Artificial Intelligence; international development management; AI adoption; benefits; challenges; policy recommendations; case studies; quantitative research; qualitative research.*

Submission ID: 251

Systematic Literature Review: Mitigating Social Isolation through Utilization of ICTs in Volunteering

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Abstract

Social isolation and loneliness present significant challenges to individual well-being in our society. This phenomenon is prevalent among young people, although they are well-connected to strong social structures, such as school, university, work environments, family and friends, social media, and other interest groups. When transitioning between these environments, they face challenges and compromise social connections, which increases risk of social isolation and loneliness. While volunteering initiatives have traditionally served as effective means to foster social connections and alleviate isolation, the integration of Information and Communication Technology (ICT) introduces a promising avenue to augment the impact. The aim of this review is to investigate the relationship between youth volunteering participation and youth loneliness, with the goal of implementing volunteering as a strategy to overcome loneliness through a digital platform.

A systematic literature review is conducted using PRISMA framework to identify relevant articles from five databases. By using keywords such as 'social isolation', 'loneliness', 'technology', and 'volunteer*', 25 relevant articles have been selected to investigate the role of ICT in volunteering to reduce social isolation among young people.

Furthermore, this research seeks to evaluate the multifaceted contributions of ICTs, including applications, webs, or virtual companionship programs. By examining how ICTs can streamline volunteer engagement processes, optimise resource allocation, provide timely and personalised support to individuals facing social isolation, this study attempts to enhance the overall effectiveness and scalability of interventions.

Preliminary findings from this review highlights how ICT integration in volunteering has the potential to help promote community wellbeing and enhance interventions aimed at mitigating social isolation.

Full Papers

Submission ID: 260

Assessing the Potential Contributions of ICT towards Ride-Sharing Services for Sustainable Transportation

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Abstract

Improving the sustainability of transportation has become a pressing concern due to the worsening urban traffic congestion and environmental pollution. Ride-sharing is gradually forming a new travel pattern by lowering the usage of private vehicles, which can efficiently lessen traffic congestion and save energy consumption. To assess the potential contributions of Information and communication technology (ICT) towards ride-sharing services for sustainable transportation, understanding the factors influencing ride-sharing utilization is important. Therefore, from the perspective of user factors, this paper aims to study the influencing factors and the potential contribution of ICT technology by doing a systematic literature review. 59 publications were ultimately found by searching for keywords and carefully examining. The findings reveal five key user factors that significantly influence ride-sharing adoption: social considerations, cost-benefit analysis, platform design, policy and regulatory frameworks, sustainable and environmental impact. At the same time, the study shows that ICT can play a pivotal role in intelligent ridesharing platforms by optimizing matching algorithms, implementing intelligent route planning, facilitating real-time information sharing, and providing personalized experiences. Based on the findings, further exploration of intelligent ICT solutions has the potential to contribute to future sustainable transportation and promote environmentally sustainable development.

Introduction

The emergence phenomena of the sharing economy as a new economic model that optimizes resource allocation and efficient social governance is changing people's lifestyles rapidly, which can achieve resource sharing by providing temporarily underutilized assets (or skill services) from resource suppliers to enhance efficiency, sustainability and possibly lowering net consumption (Curtis and Mont, 2020). As a new economic model, sharing economy provides a sustainable solution for the field of transportation. Sharing economy can effectively improve the utilization rate of transportation resources, lessen traffic congestion and pollution, lower the costs and carbon footprint, improve transportation efficiency and convenience, and environmentally friendly transportation (Bi *et al.,* 2023).

As part of the sharing economy, Carpooling, as effective tool of transportation, is a type of ride-sharing where a few people share the expense of transportation among themselves in order to utilize in a single vehicle (Hussain *et al.*, 2023). The concept of carpooling was generated in the USA in the 1970s, people usually share their rides with neighbors or colleagues due to lack of oil and rising fuel costs during that time (Parezanović *et al.,* 2019). Although people use different item to describe this new emerging

transportation, there still has the most used definition of carpooling, which is “the agreement of joining the use of a private car by several individuals frequently commuting along the same journey at jointly compatible times” (Galizzi, 2004).

Ride-sharing service is a ridesharing information intermediary based on the Internet platform, which can help passengers and drivers realize the matching and transaction of ridesharing needs. There are numerous carpooling platforms developed, and can be categorized into the following groups based on various attributes and geographical locations (Ali and Abdel-Kader, 2022). One type of ride-sharing platform is webbased, such CarpoolWorld, eRideShare, and RideSearch, which mainly post and search ride-sharing information through websites or social media (Bicocchi and Mamei, 2014). This type of platform has broad coverage, but its low security and dependability and delayed information updates. An additional option is app-based carpooling platforms, which mostly offer carpooling services via applications for smartphones like Didi and Harrow (Mitropoulos, *et al.*, 2021). While real-time matching and easy operation are two benefits of app-based systems, users must download and install applications, which carries a risk of privacy disclosure. Additionally, carpooling platforms based on networks and applications, such as BlaBlaCar UberPool and Grab, offer both websites and applications. It offers a range of options and benefits from both network and application factors; nevertheless, the drawback is requiring account registration and perhaps having platform intermediary costs (Mitropoulos, Stavropoulou, *et al.,* 2023).

Information and Communication Technology (ICT) refers to the comprehensive technical discipline that deal with the storage, retrieval and transmission of information using computer technology and communication technology (Wang *et al*., 2023). ICT plays a vital role in facilitating the transfer and sharing of information, enhancing productivity and quality of life across all industries. The design and innovation of ridesharing services is crucial to enhance the competitiveness and sustainable development of the ridesharing market (Weber *et al*., 2014). The primary contribution of ICT in the field of sustainable transportation is mainly reflected in improving transportation efficiency, lowering carbon emissions, optimizing resource utilization, etc., and supporting the development of transportation systems in a more environmentally friendly and sustainable direction (Charfeddine and Umlai, 2023). For the design and innovation of ridesharing services, ICT also can great contribute to some improvement, such as Optimization of matching algorithm for dynamic carpooling, intelligent route planning, real-time information sharing, personalized recommendation (Hong *et al*., 2017; Shen, Tziritas and Theodoropoulos, 2022; Srivastava *et al*., 2023).

Whether it is before designing a service or platform, during the development process, or during the operation phase, understanding the user is fundamental to providing better service. In the current era of frequent technological advancements and product iterations, regardless of application or network platform, the design and innovation of future ride-sharing services must take user needs, preferences, and behaviors into account in addition to the environment's features to provide a more high-quality, efficient, and sustainable ride-sharing services. To the best of our knowledge, there is no reviews are used to analyze the contribution of ICT to ridesharing services from the perspective of users. Therefore, starting from the problem, what factors affect passengers to use Carpooling? This paper is to explore the influence factors of people who use carpooling services and assess the potential contributions of ICT to ride-sharing services by adapting the systematic literature review. Section 2 brief review of existing literature, followed

by the literature selection method in Section 3. Section 4 summarizes finds through the literature from the user's factors and the technical point of view. Finally, the conclusion is conducted and discusses some improvement of these new research directions.

Literature Review

The success of a ride-sharing platform depends on the reliability of the service and user satisfaction. Some literature shows that the application of incentive mechanisms can encourage drivers and passengers to follow system rules and improve service reliability (Santos and Xavier, 2015; Zhao, *et al.*, 2015; Shen, *et al.*, 2017). In addition, privacy protection and personal safety are also very important topics in the ride-sharing platform, and the establishment of trust between drivers and passengers plays a crucial role in the platform (Vignesh *et al.,* 2018). Therefore, studying how to protect the privacy of users and ensure the safety of trips to enhance the reliability of services has also become a hot research topic in the ride-sharing platform (Almoqbel, *et al.*, 2019). However, considering users' satisfaction, it is usually necessary to consider multiple factors, such as internal factors, platform driver matching, route planning, pricing, platform design, payment method and so on; external factors, such as transportation mode and geographical location. Internal factors and external factors complement each other, so user analysis research is a key for the start development of ride-sharing platforms (Soltani *et al.,* 2021).

In the function of ridesharing platform, to help passengers find the suitable vehicle and driver quickly and efficiently, and also set reasonable platform prices, the matching algorithm of the ride-sharing platform is the key to ensure effective matching between passengers and drivers (Zhang and Zhao, 2024). ICT can significantly improve the design and innovation of ridesharing services. Some examples of these improvements include intelligent route planning, real-time information sharing, personalized recommendations, and optimization of the matching algorithm for ride sharing (Charfeddine and Umlai, 2023). With the rise of artificial intelligence algorithms in various fields, the application of deep learning or reinforcement learning to ride-sharing platforms gradually attract research attention, and researchers use reinforcement learning to optimize the matching of passengers and drivers (Zhang, Varakantham and Jiang, 2023). This includes taking into account factors such as temporal and spatial dependencies, demand forecasts, and changes in supply (Shen, *et al.*, 2022). At the same time, data mining based, or the establishment of ride-sharing matching models in the platform is very popular as well. Some studies focus on the use of large-scale traffic data for matching optimization to improve system efficiency and user satisfaction (Anthopoulos and Tzimos, 2021; Hussain, *et al.,* 2023; Srivastava, *et al.,* 2023).

In addition, ride-sharing platforms require efficient route planning to minimize detour distances and reduce waiting times for passengers (Herrera, *et al.,* 2022). For example, route planning based on time window, considering the departure time and arrival time of passengers and drivers to optimize the global optimal route matching and path planning (Li, *et al.,* 2018). Researchers are committed to considering the global optimal match and path planning of multiple passengers and drivers at the same time to reduce the detour distance (Lotze, *et al.,* 2022). Based on the route planning, it is also crucial to set a reasonable price for users. The price too high will lead to the loss of users, while too low will lead to losses for the platform and drivers, dynamic pricing strategies also need to be considered (Zhao, *et al.,* 2022). The coordination of various functions of the ride-sharing platform needs to comprehensively consider various

factors. Therefore, from the user's perspective, this paper aim at exploring the influence factors of people who use carpooling services and assess the potential contributions of ICT to ride-sharing services.

Methodology

A systematic literature review is a thorough, scientific approach to reviewing the body of literature with the goal of gathering, analyzing, and synthesizing existing research to address research questions or issues, which also can provide useful guidance and suggestions for future research and practice (Mulrow, 1994). Fig. 1 shows the SLR process used in this study, which includes six parts.

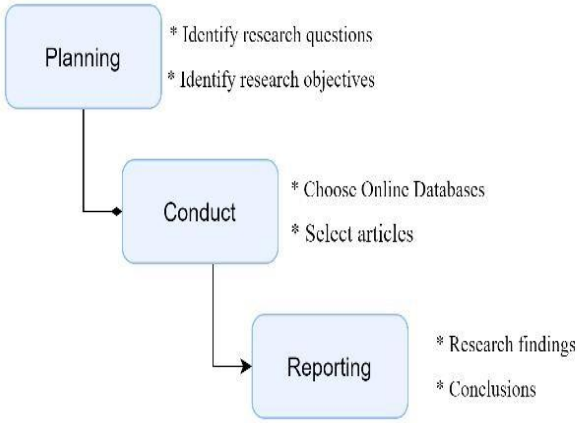

Fig. 1. Systematic Literature Review (SLR) process

Research Questions and Objectives

The research objectives of this study are mainly to assess the potential contributions of Information and communication technology (ICT) towards ride-sharing services for sustainable transportation. Accordingly, this article aims to explore the factors that affect passengers' use of carpooling service from the perspective of users. The research questions are (RQ):
RQ1: What elements influence the passenger's utilization of ride-sharing?
RQ2: What are the potential contributions of ICT for ride-sharing services?

Two primary objectives were determined to be highly relevant to the comprehension of ride-sharing services based on these questions:
Identification factors influencing both present and prospective ride-sharing users.
Synthesis and assessment of the potential contributions of ICT for ride-sharing services.

Databases Identification and Article Selection

The online databases are utilized to collect the necessary material and primary researchers by using search keywords, which include journal and conference. To address the research questions and objectives explored in this study, the elements influence the passenger's utilization of ride-sharing, and the potential contributions of ICT for ride-sharing services, scientific literature and primary studies are gathered. In the

stage of databases Identification, we choose the research period from 2021 to the beginning of 2024 published in English language searching from six datasets: Science Direct, Scopus, Google Scholar, Web of Science, IEEE Xplore, Springer. The search keywords are “ride-sharing” or “carpooling” and “ICT” and “sustainable” or “sustainable transportation” or “low carbon transportation” or “green transportation”.

In the phase of article selection, the publications that were found through the search were screened to exclude any duplicates and publications unrelated to the research topic of ride-sharing or carpooling. In this stage, a total of 136 articles were retrieved from the online databases by searching keywords. After removing duplicate publications with pointless titles during the initial screening, 84 articles were collected. After carefully examining the abstracts, in the second screening, eliminating any research that was deemed unnecessary, 59 publications were ultimately found. Among them, 32 articles were analyzed from the perspective of users and psychological behavior, and 27 articles were studied from the perspective of ICT.

Results and Discussion

User factors and ICT of ride-sharing practices have been evaluated in the research. First, from the perspective of user factors. Considering the influencing factors behind users, this chapter summarizes the user factors from different literatures and discusses the five factors that most affect ride-sharing, social factors, costs and benefits, platform technology, policies and regulations, and sustainability and environmental impact. Secondly, in terms of ICT contribution, this chapter summarizes the sustainability of ride-sharing platforms from models to platform pricing strategies and matching algorithms.

User Factors

From the perspective of passengers' behavioral motivation, the factors that affect carpooling can be divided into two categories, internal and external aspects. Internal factors starting from the user's psychology, include personal characteristics and judgment factors; While external factors include third party intervention and situational factors, which usually refers to platform and location information (Neoh, *et al.*, 2017). Based on the external and Internal factors, Mitropoulos *et al.* made improvements and groups factors into three aspects, sociodemographic, location and system factors (Mitropoulos, *et al.*, 2021). Inspired by these articles, we further divide these factors into five parts: social factors, costs and benefits, platform, policies and regulations, and sustainability and environmental Impact.

Social factors

Social factors are whether people are willing to share rides with strangers, in other words, trust in each other, and ride-sharing behaviors in different cultural contexts. Overall, studies showed that the social factors that influence people to choose carpooling services over public transportation include gender, age, job, education level, socialization, people's perception of the concept of carpooling, social background and so on (Neoh, *et al.*, 2017; AlQuhtani, 2022). The most noticeable distinction between regular participants in carpooling—drivers and passengers—is the gender distribution (Simancas *et al.*, 2024). In addition, Age and gender are generally recognized, and performance expectation (PE) and effort

expectation (EE), social influence (SI) have a major impact (Pandita, Koul and Mishra, 2021). Income level, educational attainment, reasonable working situation, and smartphone use are important variables linked to increased interest in usage of ridesharing (Soltani, *et al.*, 2021). The influence of age is not obvious, while income and education level are positively correlated with carpooling behavior. People with higher income and higher education level are more likely to participate in carpooling (Neoh, *et al.*, 2017). However, there is no absolute positive correlation between education level and carpooling, and sometimes there also is a negative correlation between different regional groups (AlQuhtani, 2022). Compared to education, the deeper understanding can be understood as people's awareness of carpooling, the level of knowledge about carpooling services and the awareness of environmentally friendly modes of transportation also attract individuals to choose carpooling services (Raza, Khan and Salam, 2023). The more people value biosphere values and altruistic values, the more likely they are to exhibit sustainable transportation behavior (Arya and Chaturvedi, 2022).

Social interaction is the main reason for carpooling. For people with the same background, such as teachers, students and workers in the same workplace, carpooling can also exchange work and study (Rey-Merchán, *et al.,* 2022). However, some studies believe that individual travel route planning will also affect the efficiency of carpooling (Gieza, *et al.,* no date). There have also been studies that separate different groups of people to study their motivations for carpooling. For the teacher, work schedule is important part, carpool with colleagues can enhance colleague relationships, but it can also lead to ongoing work problems in the car (Rey-Merchán, *et al.*, 2022). Situational factors, third-party interventions, socio-demographic factors, and psychological factors (such as socializing and feeling pleasure when carpooling with others) also influence travel choices (Rey-Merchán, *et al.,* 2022). For students' transportation choice include age, travel purpose, student group size, socio-cultural background and values, urban planning and the perfection of transportation facilities (Gieza *et al.*, 2022). Lack of public transportation, fixed schedules, distance from campus, also make students choose ride sharing (AlQuhtani, 2022). Ride-sharing services enable students from different backgrounds to meet on their way to their destinations, facilitating social interaction between them, enhancing personal relationships, and building trust (Li, *et al.*, 2023). Studies on the elderly have also been conducted; due to their strong sense of community, seniors living in rural areas are more likely to adopt more community-based ridesharing schemes (Brookhuis, n.d.). Although carpooling with the same group can promote communication with each other, it will affect the subsequent things because of the different routes. Therefore, geographical location is important factor, which affects the accessibility of the workplace, and organizational nature such as working time arrangements and activity areas determine the appeal of ride-sharing (Vanoutrive, *et al.,* 2012).

There are also some external factors that influence people's motivation for carpooling. Population densities vary throughout nations and regions, which will influence people's decision to carpool (Dey, *et al.*, 2021). People will opt to carpool in urban areas with high population density and inadequate public transit services; students are more inclined to do so (Molina, *et al.*, 2020; Kaddoura *et al.,* 2021). Cultural background influences travel decisions as well. Men with higher education, those with small families, and those who dislike walking are more likely to drive instead of ride sharing (Ayaragarnchanakul, *et al.,* 2022). In Saudi Arabia, however, group commuters, particularly women and single college students under thirty, make up

nearly half of those who carpool to school, many of these individuals are also students (AlQuhtani, 2022). Furthermore, a favorable correlation was observed between immigration status and ride-sharing activity. Americans who were born here utilize ridesharing and vehicle sharing services more often than foreigners do, whereas Americans who are immigrants utilize bike sharing and car sharing services more regularly. However, the outside variables that influence immigrants' ride-sharing are not particularly important (Lee, *et al.*, 2021). There are also studies that suggest that organized leisure is also a factor affecting people choose to carpool (Lagrell, 2024). Social context can also affect ride-sharing, in the context of the COVID-19 pandemic, where people need to maintain social distancing and wear masks, carpooling may become less important than before (Molina, *et al.*, 2020; Rasheed Gaber and Elsamadicy, 2021; Xiao, *et al.*, 2023).

Cost and benefit

Price and the convenience of regional transportation systems are also a factor in whether people choose to carpool. In the context of carpooling, the cost factor plays an important role, especially for the student group, given the limited financial situation of students and the high taxi fare, they are more inclined to carpool to reduce the financial burden (Molina, *et al.*, 2020; Raza, *et al.*, 2023). In densely populated urban areas, residents often suffer from both time and transportation costs (Kaddoura, *et al.,* 2021; Realini, *et al.,* 2021). When it comes to the fuel consumption of cars and tolls, carpooling as an efficient mode of transportation can significantly reduce the associated costs (Rey-Merchán *et al.,* 2022; Rey-Merchán, *et al.*, 2022). But there is also a research think travel cost reduction is only for the sharing way to travel, it not enough, the specific areas and the traffic situation also influence (Ayaragarnchanakul, *et al.,* 2022).

Regional factors are important when considering transportation convenience, with residents living in densely populated areas more likely to use autonomous driving, but sometimes finding a parking space or paying a toll for a long trip can also affect their motivation to carpool (Vanoutrive, *et al.,* 2012; AlQuhtani, 2022). Travelers who are willing to carpool to comparable locations should reside nearby or in the same community (Realini, *et al.,* 2021). With developed transportation, people will favor public transportation over carpooling in locations because there are more options available. But for people those who live in rural places will choose carpool since carpooling is less expensive than driving alone, (Kaddoura, *et al.,* 2021; Soltani, *et al.,* 2021). It's important to note that carpooling and rising car ownership are positively correlated. Consequently, individuals in the community who have a car-dependent mindset are more likely to look for opportunities to ride as a passenger in a carpool (Simancas, *et al.,* 2024).

Platform

Platform impact people's option of ride-sharing as well, such as the price, vehicle matching, and user experience; Individual ridesharing behavior is also influenced by the simplicity and logic of these platform features for internal pricing schemes, vehicle counts, user wait times, and route planning. Carpooling can be encouraged by a formal ridesharing system that offers up-to-date information on cost and pollution reductions (Rey-Merchán, *et al.*, 2022). The digital planning collaboration of ridesharing platforms proves that collaboration between users can create a large number of interest and behavior changes, which can greatly increase the usage of ridesharing services (Gieza, *et al.,* 2022). For different user scheduling data

simulated user behavior possible match rate, can improve the carpool with actual enforcement system related benefit estimates (Lagrell, 2024). For the elderly population, future ride-sharing services using autonomous vehicles may need to tailor transportation services to the elderly to increase their willingness to use autonomous vehicles to support their mobility and social needs (Siegfried, *et al.,* 2021). There are two types of ride-sharing services model, static and dynamic carpooling, when demand density is high, dynamic ridesharing systems can significantly improve traffic conditions, especially during peak hours (Alisoltani, *et al.*, 2021).

The development of ride-hailing platforms needs to focus on the development of content and user-friendly application interfaces to ensure that new users feel comfortable when using ride-hailing services (Shah and Kubota, 2022). In addition, platforms should customize content and information according to different regions and locations to meet the needs of users. In order to improve the user experience, these platforms should also provide payment options for multiple transaction methods, such as mobile wallets Online banking and cash make customers feel comfortable and convenient when choosing payment methods (Pandita, *et al.*, 2021). The introduction of a reputation evaluation mechanism for ride-sharing apps plays an important role in platform development. In addition to taking into account the feedback provided by other users, the mechanism should also consider users' travel preferences (Salamanis, *et al.,* 2019). At the same time, ridesharing platforms should provide loyalty-based rewards and referral-based points to increase the perceived value and benefits of using their services (Pandita, Koul and Mishra, 2021). Distrust of ride-sharing applications and inadequate technical infrastructure, in addition to security and privacy concerns about contractual ride-sharing services, are also an important obstacle, and platforms should focus on security and privacy technologies to enhance users' trust in the platform (Alok, *et al.*, 2023). These measures help to improve user satisfaction and promote the sustainable development of ridesharing services.

Policies and regulations

Policies and regulations refer to whether different regional governments encourage or restrict ride-sharing and some local policies; Policies on carpooling in different regions will affect whether local users choose carpooling. Reasonable policies will also have an important impact on carpooling (Haroon, *et al.*, 2023). Introducing an organized and regulated ridesharing program can increase the number of potential combinations of ridesharing between users and improve their chances of successful matching (Vanoutrive, *et al.*, 2012). Contractual ridesharing services are also significantly impacted by sociocultural norms and legal constraints; for this reason, legislators and pertinent parties must collaborate to address these concerns (Alok, *et al.*, 2023). The formulation of relative policies for different groups of people can also promote carpooling. For example, local governments can provide carpooling services specifically for women by developing an organized and regulated carpooling system based on the main incentives found, such as preferential prices and security guarantees (Rey-Merchán, *et al.*, 2022). For businesses and educational institutions as well as for drivers, passengers, increasing community members' willingness to rideshare can be advantageous, making a reasonable ride-sharing plan will create a positive institutional image for the organization (Simancas, *et al.*, 2024). The government is also responsible for disseminating information about the environment. The fast-changing environment has an impact on people's lives. Thus, the government should encourage environmentally friendly businesses and raise awareness of carpooling

services in order to lessen environmental destruction (Raza, Khan and Salam, 2023). On the economic front, policymakers should implement economic instruments to price personal motorized transportation fueled by fossil fuels from urban centers (Ayaragarnchanakul, *et al.*, 2022).

From the aspect of environmental policy, the government's environmental protection policy can arouse environmental concern, which can increase the use of sustainable transportation modes (Arya and Chaturvedi, 2022). However, while ridesharing services may have positive effects in terms of reducing car use, reducing CO_2 emissions and improving mobility accessibility, there may also be negative effects of competition with public transport, so future research and policy development need to take these effects into account in order to promote sustainable mobility patterns (Aguiléra and Pigalle, 2021). In the formulation of ridesharing incentive policies, we should vigorously publicize green travel and the significance of environmental protection, increase the government's subsidies for green travel, publicize the situation of road congestion in real time, standardize the ridesharing travel system of urban residents, control the number of carpoolers, and create a comfortable ridesharing travel environment (Xiao, *et al.*, 2023). For municipalities, developing high occupancy vehicle (HOV) lanes and highlighting economic and environmental benefits for potential users, while creating closed ridesharing platforms can facilitate and increase ridesharing (Molina, *et al.*, 2020).

Sustainability and environmental impact

Sustainability and environmental impact are whether users consciously choose to carpool to further reduce carbon emissions. When people gradually realize the increasingly serious traffic congestion and pollution harm to the environment, they begin to use more and more carpooling services. Carpooling can not only effectively reduce vehicles on the road, alleviate road congestion, but also reduce energy consumption to reduce environmental pollution, and become a low-carbon and environmentally friendly way of travel. People who care about the environment are more likely to participate in carpool actions to protect environment (Vanoutrive, *et al.*, 2012). The more people value biosphere values and altruistic values, the more likely they are to exhibit sustainable transportation behavior (Raza, *et al.*, 2023). In contrast, self-interested values such as protecting and promoting personal assets are significantly negatively correlated with sustainable transport behavior (Arya and Chaturvedi, 2022). Research has also demonstrated that when more people drive, carpooling has a positive knock-on impact. But overall, there is a decrease in the usage of vehicles, which results in a decrease in vehicle miles traveled (-3.8%), saving 6% of energy and reducing CO_2 emissions by 6% (Realini *et al.*, 2021). Compared with other factors, the environmental protection factor is relatively less considered by people. However, we should make more efforts to raise the awareness of environmental protection to achieve the sustainability of transportation.

Technologies

In today's urbanized world, where environmental issues are a growing concern, integrating Information and Communication Technology (ICT) into ride-sharing services could be a significant solution for

sustainable transportation. This assessment examines existing ICT applications found in literature that have contributed to ride-sharing services, in particular focusing on passenger matching, route matching, and pricing strategies.

Matching

In ride-sharing services, there are two main matching. One is passenger matching, which matches potential passengers with available drivers. When a passenger submits a travel request, the system tries to assign the request to the appropriate driver. This considers the passenger's origin, destination, departure time and other conditions (Tafreshian, *et al.*, 2020). The other is route matchin (for multiple passengers). In this case, the system needs to plan the route of multiple passengers to minimize the detour distance caused by drivers because of carpooling, thus can reduce air pollution and ease traffic pressure (Schreieck, *et al.,* 2016). Every matching is an important decision problem in ride-sharing system, therefore the passengers, the driver and the overall operating efficiency should be considered.

Based on the literature listed in Table 2, passenger matching is found to be the most popular ICT-driven approach to generate suitable rides. The passenger matching technique or algorithm uses data analysis and machine learning to connect passengers with compatible rides based on factors like proximity, destination preferences, and user ratings (Li, *et al.,* 2022; Lotze, *et al.,* 2022; Srivastava, *et al.,* 2023). This optimizes vehicle occupancy and reduces empty seat occurrences, improving the user experience and cutting congestion and emissions. It can be challenging to find a compatible carpooling companion in traditional carpooling activities, and settling on specifics like departure time, route, etc., which requires a significant amount of time and effort. By using ICT, it can create passenger matching models, which can increase carpooling efficiency and provide more convenient carpooling arrangements. The negotiation model for matching individuals (NMMI) aims to provide a matching system for carpooling based on street address and carpooling social network (CSN) through an organizational and agent-based concept to achieve matching and ride-sharing arrangements between individuals (Hussain, *et al.,* 2023). In order to form an efficient carpooling team, an algorithm that matches potential passenger trips based on travel distance in descending order is proposed, and giving priority to drivers who already have passengers for matching, which considers the relationship between passengers and drivers as well as the constraints between trips (Rasoldier, *et al.,* 2023).The combination of genetic algorithm and branch and bound algorithm can also effectively optimize passenger allocation to solve the multi-objective optimization problem in the peer-sharing model to balance passenger time and cost (Hasanpour, *et al.* 2022). Using a combination of distributed ledger technology (DLT) and social practice theory, a practice-based decentralized community model is proposed that allows for the publication of electric ride-sharing services by drivers, connecting them directly with passengers and eliminating the need for reliable third parties (Anthony, 2024).

For route matching, ICT can also help to optimize routes in real-time by predicting traffic conditions and adjusting routes accordingly. This ensures timely arrivals and minimizes travel time by aggregating

multiple ride requests along similar routes. By adapting to changing traffic conditions, ride-sharing services become more efficient and eco-friendlier. A dynamic ridesharing model based on the XGBoost model connects individuals to appropriate routes and schedules by reducing the number of cars required for individual travel and increasing available seat capacity, thereby improving ridesharing efficiency, reducing the number of trips and saving travel distances (Srivastava, *et al.,* 2023). Path planning can also be effectively realized by genetic algorithm and branch and bound algorithm (Hasanpour Jesri and Akbarpour Shirazi, 2022). Considering the randomness of carpooling and the delay of route time, the combination of heuristic algorithm and survival analysis technology can better guide the meta-heuristic search in the solution space of random carpooling problem by using simulation feedback (Herrera *et al.,* 2022). By putting private car drivers' total transport costs and incentives; Grievances determined by employee walking distance, travel time and delays to work; Taking into account the three factors of total carbon emissions generated by commuting, there are also studies based on Pareto intensity ant colony optimization (PSACO) that can be used to solve the problem of minimizing the objective function of carpool route matching (Asghari, *et al.*, 2022). The selection of meta-heuristics is gaining increasing traction. The ride-sharing problem can be successfully resolved by research that uses a combination of heuristics and exact approaches, or that solely uses heuristics and/or meta-heuristics and/or other solutions, such simulation techniques (Martins, *et al.*, 2021). Additionally, ridesharing could be optimized by using the new language model (LM), machine learning and data mining to develop more sophisticated algorithms for drivers and passengers matching and also routes matching. These models may dynamically improve routes, taking into consideration factors like traffic congestion and preferred routes, by reviewing previous routing and navigation decisions. This ensures that both drivers and passengers save time (Mitropoulos, Kortsari, *et al.*, 2023).

There are also studies that combine user matching and route matching for dealing with ride sharing optimization problems. Deep reinforcement learning technology can solve the joint optimization problem in ride-sharing system, improve service efficiency, reduce passenger waiting time, and maximize the use of vehicle resources (Manchella, *et al.*, 2021). At the same time, there are also studies using a novel 2-layer reinforcement learning method, adding the future perception model to the joint matching and pricing model, to centrally optimize the ride-sharing problem. Additionally, from a social perspective, ride-sharing is influenced by social networks. There has a research by combining social networks with ride-matching and route optimization technologies, in this way to lower obstacles to ride-sharing participation (Anthopoulos and Tzimos, 2021). In summary, from the user's point of view, machine learning, heuristic algorithms, and some joint algorithms can alleviate users' pain points and make carpooling easier and more effective by solving problems such as matching difficulties, scheduling, information asymmetry, and inefficiency of the ridesharing system.

Pricing

Additionally, pricing determination using ICT is used to adjust dynamically the fares based on demand, time of day, and route congestion. This encourages passengers to choose shared rides during off-peak hours or

congested routes. Transparent pricing and promotions build trust and loyalty among users, encouraging them to adopt sustainable transportation options (Zhang, *et al.*, 2023). By combining the dynamic pricing model with the consumer social learning network model and using the reinforcement learning algorithm to simulate the model, the consumer's perceived sensitivity to different travel modes can be evaluated, and the market share and price can be dynamically adjusted (Zhang and Zhao, 2024).

Augmented epsilon constraint (AUGMECON) and nondominated sorting genetic algorithm 2 (NSGA II) is used order to find a cost - and time-based non-dominating solution within an integer biobjective optimization model integrating vehicle routing and passenger allocation (Hasanpour Jesri and Akbarpour Shirazi, 2022).

Pricing strategies for ridesharing models can also be further adjusted by taking into account the heterogeneity of consumer preferences and the impact of different service types offered by drivers, thus striking a balance between the cost of service and the benefits of quality drivers (Ma, *et al.*, 2024). There are also studies on the establishment of models under the background of price fairness, competition and government regulation, and unified pricing, differential customer pricing, differential driver pricing and bilateral differential pricing to achieve the optimal pricing strategy of the platform through dynamic pricing (Zhao, *et al.,* 2022). As the price of ride sharing is affected by different factors, it is necessary to add these factors into the pricing model, such as weather, demand, traffic conditions, etc. At the same time, users have different price sensitivity, the quantification of price sensitivity can also be added to the pricing model. By using deep learning, machine learning, or other ICT technologies to solve these problems. However， pricing strategy and matching problem are considered to be very dependent, so it is also necessary to combine passenger matching and route matching to solve the pricing of carpooling (Manchella, *et al.,* 2021; Zhang, *et al.*, 2023).

Others

In creating a suitable APP or system development for users, CT contributes to some front-end technologies and back-end technologies, such as HTML5, CSS3, JavaScript, API interface development, database and so on (Sheng and Yasak, 2021; Ferrada, *et al.*, 2023). According to the user's needs and pain points, in addition to the basic functions of the platform, other functions will also be taken into account by developers. Baselined Gated Attention Recurrent Network（BGARN） to solve the request prediction problem in ride-sharing. By accurately predicting requests from passenger, the ride-sharing platform can schedule vehicle scheduling in advance to maximize vehicle utilization, reduce waiting time and improve service efficiency (Shen, *et al.*, 2022). Through the integration of Traffic Analysis Zone (TAZ), which utilizes the rasterization technique, with the maximum possible distance (MPD), which is the trip mode's furthest travel radius. This can be applied to evaluate how ride-sharing services affect the robustness of urban transportation networks (Li, *et al.*, 2022). It is also pointed out that agile optimization (AO) algorithms, which appears as a new optimization and decision tool for solving optimization problems in real time, can provide real-time solutions for the future ridesharing optimization strategies (Martins, *et al.*, 2021). The advantages of blockchain technology's centralized peer-to-peer network that cannot be tampered with can help realize the logic and payment problems of centralized ride-sharing platforms (Aschauer, *et al.*, 2023). In addition, in the security and privacy issues that users worry about, blockchain technology can also be a good solution to the privacy and trust issues between organizations (Zonda and Meddeb, 2020).

Table 1. Summary of user factors

	Literature	*Social*	*Cost Benefit*	*Platform*	*Policies Regulations*	*Environmental Impact*
1	(Rey-Merchán, López-Arquillos and Pires Rosa, 2022)	*	*	*		*
2	(Rey-Merchán *et al.,* 2022)	*	*	*		
3	(Vanoutrive *et al.,* 2012)	*	*			
4	(Ayaragarnchanakul *et al.,* 2022)	*	*			*
5	(Gieza *et al.*, 2022)	*		*	*	
6	(Raza, Khan and Salam, 2023)	*			*	*
7	(Sofi Dinesh, Rejikumar and	*				
8	Sisodia, 2021)	*				
9	(AlQuhtani, 2022)	*				
10	(Simancas *et al.,* 2024)	*	*			*
	(Chou *et al.,* 2024)		*			*
11	(Lagrell, 2024)	*		*		
12	(Arya and Chaturvedi, 2022)	*			*	*
13	(Xiao, He and Wang, 2023)	*		*		*
14	(Kaddoura *et al.,* 2021)	*		*		*
15	(Mishra, no date)	*	*			*
16	(Pandita, Koul and Mishra, 2021)		*			
17	(Alisoltani, Leclercq and Zargayouna, 2021)		*			
18	(Si *et al.,* 2023)	*	*			*
19	(Lee, Smart and Golub, 2021)	*		*		
20	(Lim *et al.,* 2022)			*		
21	(BrookhuiS, 2023)	*				
22	(Siegfried *et al.,* 2021)			*	*	
23	(Realini *et al.,* 2021)		*			
24	(Mohammad, Mahmud and Hoque, 2022)	*	*			*
25	(Wainaina and Mutogoh, 2022)			*		*
26	('Evaluation and Analysis of User Satisfaction of Ride-Sharing Service: An Assurance and Empathy in Bangladesh Perspective', 2021)		*		*	
27	(Lee, Smart and Golub, 2021)	*				
28	(Siegfried *et al.,* 2021)	*		*		
29	(Mehnaj, Raida and Murshed, 2023)	*	*			
30	(Soltani *et al.,* 2021)	*				
31	(Rasheed Gaber and Elsamadicy, 2021)	*				
32	(Tavory, Trop and Shiftan, 2023)	*	*			*

Table 2. Summary of ICT.

	Literature	*Matching*		*Pricing*	*Others*
		Passenger Matching	*Route Matching*		
1	(Shen, Tziritas and Theodoropoulos, 2022)	*			
2	(Herrera *et al.,* 2022)		*		
3	(Lotze *et al.,* 2022)		*		
4	(Asghari, Al-e-hashem and Rekik, 2022)		*		
5	(Sun, Chen and Guo, 2022)	*	*		
6	(Li *et al.,* 2024)				*
7	(Martins *et al.,* 2021)	*			
8	(Manchella *et al.,* 2021)	*	*	*	
9	(Ray and Khedira, 2023)				*
10	(Ma, Tao and Wei, 2024)			*	
11	(Srivastava *et al.,* 2023)	*		*	
12	(Hasanpour Jesri and Akbarpour Shirazi, 2022)			*	
13	(Zhao *et al.,* 2022)			*	
14	(Sheng and Yasak, 2021)				*
15	(Anthopoulos and Tzimos, 2021)	*			
16	(Anthony, 2024)	*			
17	(Aschauer, Sonnleitner and Kurz, 2023)				*
18	(Ferrada *et al.,* 2023)				*
19	(Zhang, Varakantham and Jiang, 2023)	*		*	
20	(Dai *et al.,* 2022)		*		
21	(Hussain *et al.*, 2023)	*			
22	(Mitropoulos, Kortsari, *et al.,* 2023)		*		
23	(Rasoldier *et al.,* 2023)	*			
24	(Li *et al.,* 2022)				*
25	(Zhang and Zhao, 2024)			*	
26	(Tomás *et al.,* 2021)				*
27	(Sahebdel *et al.*, 2023)				*

Conclusion

ICT integration holds promise for sustainable transportation through ride-sharing. By optimizing passenger and route matching and implementing dynamic pricing, ride-sharing platforms can reduce congestion, emissions, and travel time. Overcoming challenges like privacy and equity issues will be essential for realizing the full potential of ICT in creating a more sustainable transportation future. While ICT offers great potential, challenges like privacy concerns, algorithm biases, and infrastructure limitations must be addressed. Regulations and technological safeguards are needed to protect user data and ensure fairness. Additionally, ensuring equal access to ICT-enabled ride-sharing services across different socio-economic groups is crucial for inclusive and sustainable transportation. The future development of carpooling services can be deeply studied from the following aspects：

- Intelligent algorithms：Research and development of intelligent algorithms such as machine learning and deep learning to optimize ride-sharing matching and trip scheduling processes, which will improve matching efficiency and accuracy, thereby improving the user experience.
- Social considerations：Study the influence of social factors among individuals on carpooling activities. For example, trust and preference matching are critical to ridesharing matching success and user satisfaction. Additionally, building a social network in a ride-sharing model and push users with similar preferences.
- Eco-friendly ridesharing: Encourage eco-friendly ridesharing transportation and promote shared vehicles to save carbon emissions for improve rideshare in a more sustainable way. At the same time, community activities can enhance people's awareness of environmental protection. Thereby ride-sharing services can be studied from an environmental perspective.
- Real-time road condition consideration: Integrating real-time traffic data and researching ways to optimize travel plans, cut down on traffic and travel time, and enhance user happiness by considering real-time road condition information when carpooling.
- Personalized services: Future research can study how to offer carpooling services that are tailored to the individual needs and preferences of users. This will improve user satisfaction and increase the suitability of carpooling for a range of user requirements.
- Policy and regulation: For government departments, research on how to provide policy support and regulation formulation in the field of carpooling, standardize carpooling activities and promote sustainable development is also critical in the future.

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10b. Sustainability in the Himalayan Region

Abstracts

Submission ID: 37

Shifting Linkages: Agro-Pastoral Changes and the Emerging Role of Domestic Dogs in the Indian Trans Himalayas

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Abstract

Mountain areas across the globe have been going through unprecedented rates of changes due to climate change, land-use changes and globalization compromising critical ecosystem services and human well-being. In a system where communities are dependent on natural resources for their livelihoods, externalities in the form of government policies and development interventions can have unexpected consequences. Our study investigates agropastoralism changes across a decade in the Upper Spiti Landscape (Himachal Pradesh, India) and evaluates these changes in the larger framework of ecological and social perturbations particularly with respect to human-dog relationships. We conducted 256 semi-structured interviews across 27 villages in the landscape as well as compared livestock trends across 26 years through secondary data. Nearly 72% of the respondents reported a decline in the livestock population in the last one decade (2003-2013). The landscape witnessed a 44% decline in the population of livestock in the last 10 years with a significant reduction in small-bodied livestock. More than half of the respondents did not have small-bodied livestock (59%) and for 40% of these respondents, this change happened in the last 5 years. Though several reasons of decline were stated, livestock depredation by dogs was most frequently stated reason comprising in 66% of the responses. Overall, livestock population decline along with government schemes to increase area under agriculture resulted in accessing manure from outside. While lifestyles changes triggered by socio- economic changes have contributed to the initial declines in livestock, in the last decade, livestock depredation by dogs have resulted in the decline of small-bodied livestock as well as impediments in herding them. In the Trans-Himalayan arid landscape of the Upper Spiti valley, the interactions between traditional livelihood, and external market driven economics has produced an unlikely keystone player, the domestic dog, whose impacts have been disrupting the intricately linked production systems. This reiterates the need for concerted efforts by multiple agencies in dog population management in the landscape.

Submission ID: 124

Estimation of Environmental Impact Generated by Tourism and Mountaineering Activities in Sagarmatha National Park

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Abstract

Climate change and tourism are having a significant impact on mountain ecosystems and local communities' lifestyles. Local communities in mountainous areas benefit from ecosystem services generated by the mountain environment, however, have limited adaptive capacity to the impacts of climate change due to limited livelihood options. Understanding the impacts of climate change on local communities is an urgent issue in terms of sustainable mountain environment conservation. These analyses require baseline data collection through field surveys, but due to the difficulty of accessing the field, few studies have been conducted on the impacts on cultural ecosystem services of alpine peoples.

This study reports on a baseline study conducted in a mountainous area of the Himalayas, a leading tourist destination visited by trekkers, to elucidate the environmental impacts on the social environment caused by direct and indirect environmental load associated with mountaineering and tourism use. The target area of this study is Sagarmatha National Park (SNP) in the Khumbu region of northeastern Nepal, which includes the world's highest mountain, Mt. Everest, and is one of the most developed mountain tourism areas in Nepal, with its foothills serving as a major trekking route, but also imposes significant environmental impacts. Field surveys in Everest Base Camp (EBC) on the Nepal side from 2003 to 2005 was conducted. From these surveys, the authors clarified that a large number of organic wastes such as human feces, urine, and miscellaneous domestic wastewater are discharged during the stay at the base camp due to mountaineering activities, polluting the water environment, and attempted to calculate the amount of environmental load. Based on the research obtained to date, this study estimates the environmental load within SNP.

Here we treated the example of the year 2019, the most visited year since the statistical history of the SNP: the number of visitors to the SNP in 2019 was 58,030. From previous studies, the average length of stay of visitors in SNP is 14.5 days. To estimate the environmental load, the amount of human organic waste (feces and urine), which hypothetically has the greatest impact on the environment, is taken as one of the variables. The intensity of human organic waste is 0.11 kg/day of feces and 1.5 liters of urine. Converted to units by weight, the specific intensity of organic waste discharged from humans is 1.61 kg/day. Multiplying the number of visitors, the intensity of organic waste generated, and the average number of days spent in the area, the environmental load in 2019 was estimated to be approximately 1,354.7 t. our findings suggest the possibility of calculating the carrying capacity necessary to consider sustainable mountain environment conservation measures by clarifying the mechanism and environmental load due to tourism use in SNP on local communities. SDG+Target: 13.2 and 15.4 Linking Futures of Mountain and Ocean: Clarifying the impacts of Climate Change on Cultural Ecosystem Services in the High Mountain areas and Proposing Adaptation Masseurs

Submission ID: 200

Priority Areas for Conserving Biodiversity and Threats in the Pan-Himalaya

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Abstract

Biodiversity conservation is crucial in the face of increasing environmental challenges, requiring accurate extraction of biodiversity data for informed decision-making. The Pan-Himalayan region holds significant economic and ecological importance, linked to China's Belt and Road Initiative (BRI) and the conservation goals of the 15th Conference of the Parties (COP15). However, there is limited knowledge about its habitats and areas with threatened flora and fauna. Climate change poses a major threat, affecting habitat patterns and species adaptations. This study aims to assess the conservation status of endangered plant and animal species in the Pan-Himalayan region. Using various methods such as field monitoring, surveys, and GIS spatial modeling, the research will use the MaxEnt model to assess habitat suitability for target species. INVEST will be used to calculate ecosystem service functions and analyze stress factors. Mapping these data will help identify areas for plant and animal conservation and restoration based on ecological corridors. To address the lack of information on habitat distribution and hotspots, a "Basic Geodatabase of threatened flora and fauna" will be created. The study will also examine the role of protected areas in conserving biodiversity and ecosystem services, crucial for effective conservation. Historically, biodiversity studies focused on individual regions, neglecting the Pan-Himalayan region's diverse physical geography and geological history. This project will highlight these subunits to propose strategic conservation planning, serving as a model for similar regions.

Full Papers

Submission ID: 136

Towards Source Mapping for Sustainable Materials during Post-Disaster Reconstruction

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Abstract

Nepal is prone to natural disasters including landslides, earthquakes, floods and forest fires. As a result, many buildings and infrastructure are affected, and lives are lost frequently. The effects of the natural disasters are even more prominent in the mountainous regions due to poor road infrastructure. Recent trend in construction of houses, especially following the 2015 Earthquake, has seen popularity in using concrete as the choice construction materials even in remote places where steel, cement, sand and aggregate are not easily available and requires trades people from outside of the local areas. In such situations, locally sourced materials can provide cost-effective and fast alternatives. This study aims to develop a source map for locally available sustainable construction materials to help the reconstruction work in post-disaster scenario. Following the field trips in Sindhupalchowk district after 2015 earthquake, this paper presents the importance of using locally sourced materials for sustainable and responsible reconstruction work using sustainable materials and locally available manpower. Field data from reconstruction projects following 2015 earthquake provide background for creating source map. Visual representation of both sources of construction materials and delivery processes, including estimated time, can assist in effective decision making for re-building the disaster affected areas.

Introduction

Nepal is located in a seismically active area and was hit by a 7.8 Richter scale earthquake in 2015. More than 500,000 buildings were destroyed including private houses, community buildings, schools, heritage buildings and attractions. Several rebuilding/reconstruction projects were undertaken in Nepal following the 2015 earthquake. These projects were a mix of residential houses, community and government buildings as well as heritage buildings. Construction of a number of roads infrastructure projects were also undertaken.

Whilst majority of buildings, especially those outside the Kathmandu valley, had been built using locally available materials such as mud brick, stone rubble and timber, newer construction materials such as steel and concrete were used during the reconstruction process. These newer materials were either imported from India or were sourced from other parts of the country.

The main objective of this study is to develop a visual map showing the source and supply path of construction materials used in reconstruction work in Nepal following the 2015 earthquake. To achieve this objective, following steps have been identified.

- Identify key construction materials used in the re-construction works.
- Identify source and supply path of these materials and
- Map the source and supply path of the materials using geographical information systems (GIS).

Visual source of map of construction materials will provide a quick access to potential construction materials for future construction activities. It will be accessible by government organisations as well as non-government organisations (NGOs), International NGOs, international aid agencies and donors. Access to a visual source map of construction materials should facilitate and enhance the humanitarian services especially in a post-disaster re-construction scenario.

In April 2015, a 7.8 magnitude earthquake affected many districts within Nepal, through the destruction or damage of buildings and infrastructure and loss of life. One of the most affected districts was Dolakha. The centre of Dolakha, Charikot (Bhimeshwor Municipality) is located approximately 135 km east of Kathmandu (Figure 1).

Figure 1. Districts of Nepal (DUDBC, Government of Nepal 2018)

In this study, typical construction materials used in the reconstruction of buildings in Dolakha have been identified and major suppliers have been located. In the process, the investigation has also brought key challenges regarding construction materials to the surface.

Analysis of supply chain of typical construction materials utilised in housing reconstruction has led to collection of necessary data to create a “source map”. The source map is a visual indication of where suppliers are located, to help quickly locate construction materials in case of future earthquakes or other natural disasters in Dolakha. Additionally, the study also identified use of locally sourced materials in the reconstruction process.

Approach

The purpose of this study was to identify the key construction materials that has been used in the reconstruction project area and investigate how they are sourced. Semi-structured and informal interviews with relevant stakeholders were conducted in the field. The interviews also identified sources of locally available alternative construction materials in those areas. Interviews assist to develop a full picture of the supply chain of main construction materials used. The supply chain of both locally sourced construction materials and other construction material will be compared from accessing time, delivering and their potential impacts to environment.

Based on these interviews with the stakeholders, a database will be created which will link each project to the materials being used and each material to their supply chain. Moreover, locally available construction materials as alternative sources and their location will also be recorded.

A visual map of the supply chain will then be created as a system to help all the stakeholders in the future reconstruction projects.

The approach used in this study can be summarised in the following 6 stages.

1. Identify study area based on reconstruction activities
2. Identify number of reconstruction projects and materials used
3. Locate and list the number of suppliers and source of materials used in reconstruction
4. Record the location of the suppliers and time it takes to deliver to the zone
5. Create a supply chain source map from above information
6. Evaluate the source map, and therefore answer the questions posed within the project objectives

In Stage 1, Dolakha was selected as the study area based on discussions with National Society for Earthquake Technology (NSET) Project Director and Head Engineer.

Stage 2 was undertaken through a desktop study and following online resources available through the following organisations in Nepal were used for this purpose.

- National Reconstruction Authority (NRA)
- National Society for Earthquake Technology (NSET)
- Housing Recovery and Reconstruction Platform (HRRP)
- Ministry of Urban Development – Central Level Project Implementation Unit (MoUD – CLPIU)
- Ministry of Federal Affairs and Local Development – Central Level Project Implementation Unit (MoFALD – CLPIU)
- Federation of Nepalese Chamber of Commerce and Industries (FNCCI)
- Federation of Contractors' Association of Nepal (FCAN)

In stages 3 and 4, fieldtrip to Dolakha was undertaken for data collection using predetermined questionnaire. Following activities were conducted during the field trip to facilitate the collection of essential data.

Survey the teams at the District Reconstruction Technology Centre (DRTC) and Local Reconstruction Technology Centre (LRTC) to gather information on supply chain logistics

Survey supervisors on numerous existing projects

Visit major factories or production centres of construction materials identified in Stage 2 to identify where the materials are delivered to

Verify list of housing construction materials to include all those identified in stage 2 and note any additional materials missed

During the field trip, reconstruction projects on residential buildings in two areas in Dolakha, Ganesh Tole and Chathali, were surveyed and first-hand data was gathered based on discussion and interviews with people involved in the projects. People interviewed in the study included engineers from NSET, social mobilisers, homeowners undertaking re-construction, local level elected representatives from the study area, suppliers of construction materials in Charikot and block manufacturer.

Following the field trip, a desktop analysis was conducted as part of stages 5 and 6 to create the supply chain source map.

Results and Discussion

The field trip and desktop analysis identified the most commonly built design of the house in the reconstruction area, stone masonry in cement mortar, in short SMC. The model of SMC is shown in Figure 2. It has a total of four main rooms (including 2 bedrooms and 2 common areas) and is suitable for at least four residents. The other alternative building types are brick masonry in cement mortar (BMC) and reinforced concrete construction (RCC). However, the lack of popularity of these types is evident by 26 out of 33 houses in Chatali (Dolakha) being of stone construction, 2 brick construction and 4 RCC type.

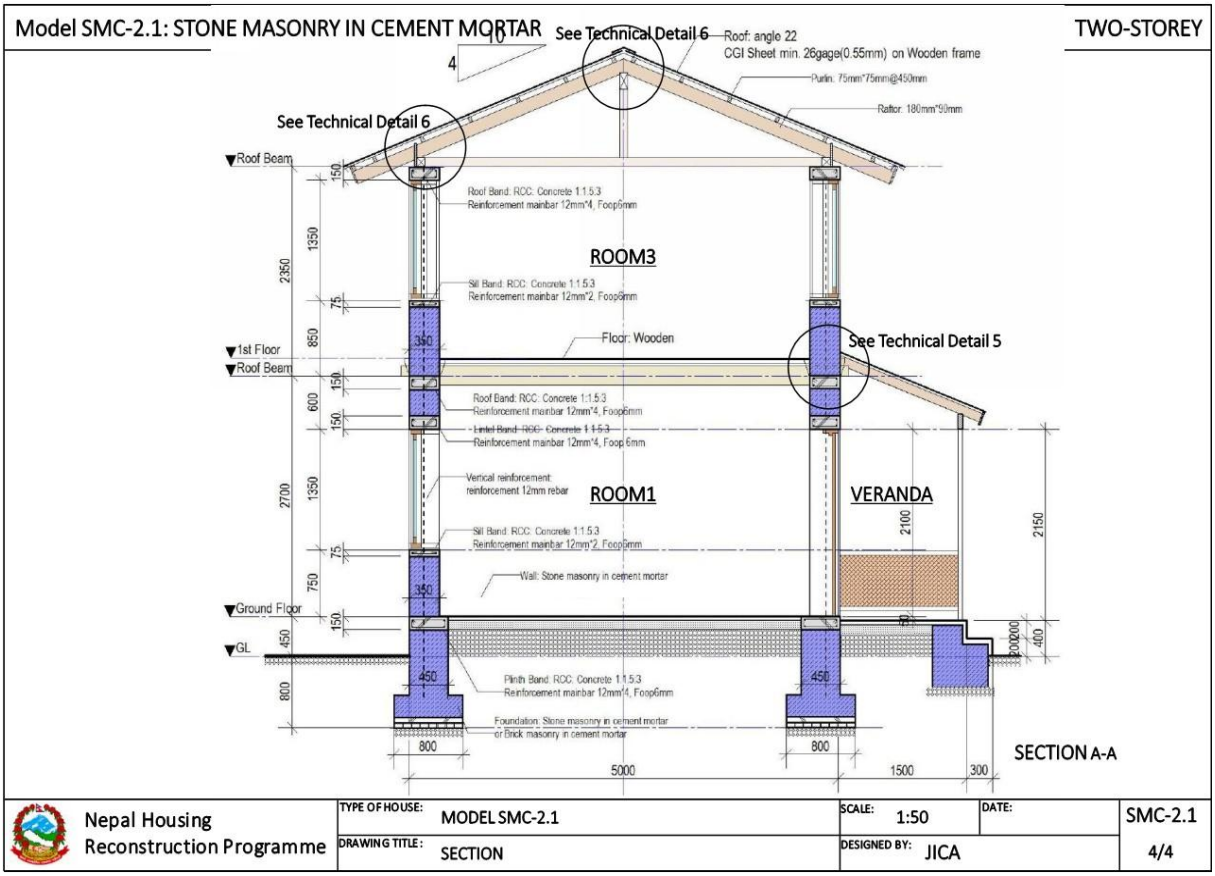

Figure 2: Model SMC-2:1: Stone Masonry in Cement Mortar – Typical Section
Government of Nepal, Ministry of Urban Development, 2015

Table 1 below shows the estimated material quantities for the most typical housing reconstruction design (SMC2.1) from the DUDBC Design Catalogue, as noted above. Additionally, it is important to note that the MoFALD Report (Annexure 6) states that 30mm^3 of 50m^3 stone and 0.6 of 2m^3 timber can often be reused from the demolished house. Therefore, requiring an additional 20m3 of stone and 1.4m^3 of timber.

Table 1. Construction materials and quantities for typical house construction

Material	Unit	Source 1: MoFALD	Source 2: DUDBC	Final estimate
Stone	m^3	50	48	49
Cement	Bags	220	187	203.5
Sand	m^3	30	29	29.5
Aggregate	m^3	14	10	12
Timber	m^3	1.98	4.43	3.21
CGI sheet	Bundle	n/a	3.69	3.69
Steel	Kg	n/a	252	252

Note: *Data gathered from a combination of the Report by the Ministry of Federal Affairs and General Admission (MoFALD) - 'Environmental and Social Screening Report', and DUDBC Publication - 'Design Catalogue for Reconstruction of Earthquake Resistant Houses'.*

Data collected from the interviews conducted during the field trip to Dolakha identified the location of suppliers of construction materials identified in Table 1 above and how these materials were transported to the construction site. It is detailed below in Table 2.

Table 2. Location of suppliers and transportation for the construction materials identified in Table 1

Materials	Location of Supply Source	Transportation	Distance (km)	Delivery Time (A)	Delivery Time (B)	Original Source (Factory/quarry)	Locally Sourced (Y/N)
Stone	Dolakha	N/A	0 km	0 hrs	0 days	Existing structure	Yes
Brick	Bhaktapur, Bardibas	Truck	120 km, 160 km	5 hrs, 5 hrs	1 day	Factory	No
Cement	Birgunj, Bhairahawa	Truck	275 km, 475 km	8 hrs, 12 hrs	2 days	Factory	No
Sand	Tamakoshi, Koshikhet	Truck	20 km, Note 1	1 hr, Note 1	2 hours	Quarry	Yes
Aggregate	Tamakoshi, Koshikhet	Truck	20 km, Note 1	1 hr, Note 1	2 hours	Quarry	Yes
Wood	Kathmandu (Sal wood), Charikot (local wood)	Truck	135 km, Note 2	6 hrs, Note 2	6 hours / 1-2 hours	Forest	Yes & No
CGI sheet	Birgunj	Truck	323 km	10 hrs,	2 days	Factory	No
Reinforce-ment Bars	Birgunj, Bhairahawa	Truck	323 km	10 hrs,	2 days	Factory	No
Others:							
Blocks	Charikot, Dolakha	Truck	0 km	0 hrs	1-2 hours	Factory	Yes
Plywood	Chothang	Truck	2 km	0.2 hrs	1-2 hours	Factory	Yes

Note*: Delivery Time A denotes duration to drive vehicle from stated location to Charikot, sourced from Google Maps. This excludes any travel breaks and contingencies for delays (for example, breakdowns, traffic).*
Delivery Time B denotes realistic duration of transportation of materials, as quoted by the hardware store owners in Charikot. This includes any travel breaks and contingencies for delays.
Delivery distance and time depends on specific location being delivered to from Charikot. Additional estimates to individual construction sites be calculated from basis of Charikot.
Calculations for delivery distance and time based on delivery to Charikot, where hardware suppliers act as major distributors.
Data collected from Charikot, Bhimeshwor Municipality in Dolakha

In conjunction with Table 2, it is important to acknowledge that data regarding delivery time and distance for cement, sand and aggregate from Koshikhet was not available, as exact location of supply from the Koshikhet River was not identified. Additionally, delivery distance and time depends on specific location of forest in Charikot, where timber is being sourced from.

Based on the data presented in Table 2, a source map for the construction materials used in typical building in Dolakha district was created (Figure 2). An interactive version of source map and routes was developed with Zeemaps (https://www.zeemaps.com)

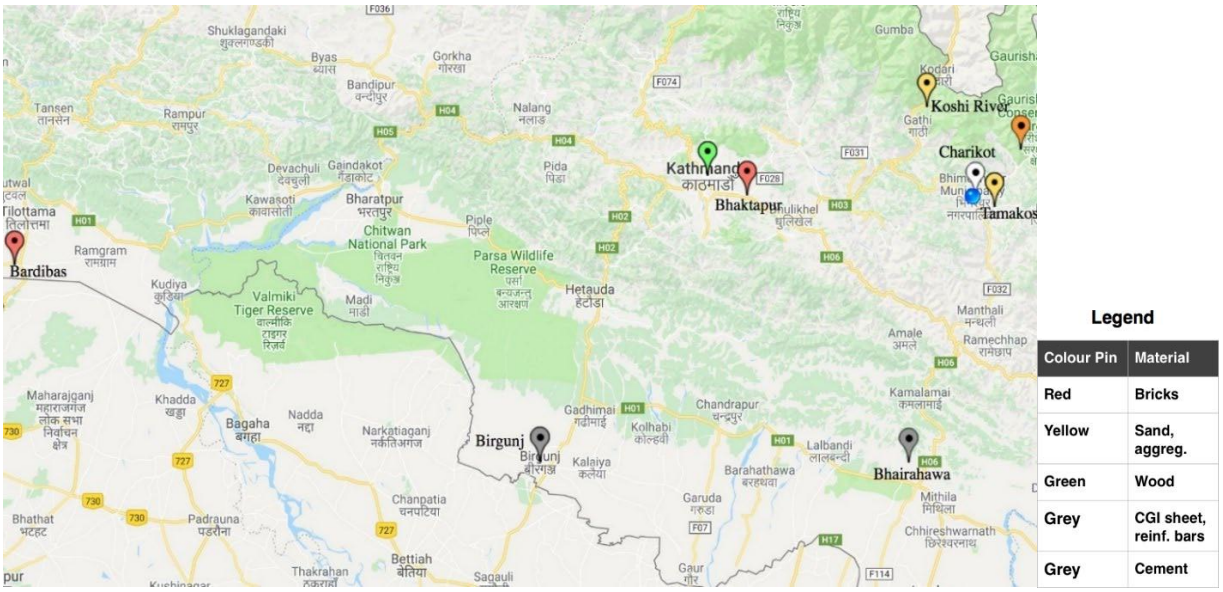

Figure 3. Source map of construction materials for buildings identified in Dolakha district

Conclusion

The study successfully identified the status of housing reconstruction in Dolakha in 2018 and sources of construction materials commonly utilised. It was found that majority of construction materials were being supplied from the Terai Region (the south of Nepal), as the proximity allows for the import of materials to either be supplied directly or in the form raw materials for manufacturing typical construction materials.

The study also unveiled numerous key challenges faced by owners and builders in Dolakha, regarding the procurement of construction materials. The greatest challenge of these has been identified to be the Government-imposed ban of the extraction of sand and aggregate from the Tamakoshi River, at the time of reporting in 2018. Due to heavy demand and reliance upon this local source, the impacts on owners and builders at the time, were significant. This has not only increased prices of sand and aggregate, but also caused major delays to completion, with the consequence of potentially failing to meet deadlines for tranche payments by the Government of Nepal. An additional major challenge has been in transportation. Two key causes of this have been poor infrastructure (of roads) and therefore limited access to remote

construction sites in Dolakha, and the government regulation changes in prohibiting heavy goods to be transported on major roads (directly linking Terai Region to Charikot) at the time of reporting.

The below recommendations are proposed, specifically to alleviate the supply challenges of construction materials in Dolakha:

Organisations should provide greater education and training on block masonry (including properties, buildability, installation methodology), due to its introduction as a relatively new material.

Government bodies and Ministries should investigate the potential issue of lack of consistency of blocks produced and regulate standard sizes within national building codes and standards, that are acceptable to ensure fair and equal distribution of work among factories and suppliers in Dolakha.

Government should revise planning before implementing bans (for example of sand and aggregate from the Tamakoshi River or prohibiting transportation of heavy goods on selected major highways).

Government should allow for and propose alternative sources of construction materials, if and when implementing a ban, so that local residents avoid financial loss through significantly inflated prices or resort to the illegal procurement of materials. This will remove this barrier to compliant re-construction.

If such bans will likely cause delays to due dates for tranche instalments, then a reasonable extension should be given and clearly publicised to avoid confusion among the public.

Serious consideration should be given to investing in new factories of construction materials within Dolakha region itself, to avoid reliance on imported materials from India and eliminate the need for costly and slow delivery.

Greater degree of collaboration should be encouraged between local representatives (such as Mayors) and the local residents undertaking reconstruction of their homes. This should be achieved through frequent, facilitated workshops or meetings to openly discuss and resolve challenges or issues regarding the procurement of construction materials.

Acknowledgment

We would like to acknowledge the assistance of the National Society for Earthquake Technology-Nepal (NSET) for facilitating field trips to execute this study and for access to local teams, who were well informed on the status of reconstruction in Nepal, following the earthquake in 2015.

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10c. Religious Philosophies and Sustainable Development

Abstracts

Submission ID: 223

Pre-Service Science Teachers' Perceptions Regarding the Theocentric Worldview of Education for Sustainable Development (ESD)

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Abstract

The ecological crisis facing humanity today can be viewed as a consequence of transgressing the delicate balance that exists within ecosystems. The inherent tensions arising from the integration of development and conservation so far have compelled numerous individuals and organisations to grapple with the continuum between anthropocentric and biocentric orientations. This paper advocates theocentrism as a conceptually and practically effective way to reconcile these conflicting worldviews. Faith possesses significant potential by leveraging on its ethical principles in order to call for the transformation of the minds and attitude of every individual. In pursuit of this goal, this ongoing case study investigates the integration of theocentric worldview of Education for Sustainable Development (ESD) and outdoor environmental education as an alternative and holistic approach to implement the sustainability curriculum. The topic is explored from the perspective of pre-service Science teachers in regards to the efficacy and practicality of the integrated approach in their teaching practice. Twenty final year undergraduate students studying to become Science teachers will participate together in an outdoor program that integrates this worldview. Using reflection questionnaires as well as photo elicitation focus group discussions, this study aims to explore (i) pre-service Science teachers' perception on the approach and (ii) their self efficacy to apply the approach in their own teaching. By tailoring ESD to fit into the Malaysian religious context, the alternative and holistic approach could potentially serve as one of the practical strategies to push for a more effective sustainability curriculum. This research could also provide valuable information regarding teacher preparatory courses in the Malaysian college of education.

SDG +Target: 4.7, 12.8, 13.3 (Education for Sustainable Development)

***Keywords**: Theocentric; Education for Sustainable Development (ESD); Outdoor learning*

Submission ID: 286

Sustainable Waste Management in Restaurants: An Islamic Managerial Approach Supporting SDG 12

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Abstract

Restaurants and food courts are significant contributors to solid waste generation in the commercial sector, comprising leftover food and damaged kitchen equipment. These waste streams not only pose environmental challenges but also result in substantial financial losses. Effective waste management strategies are imperative, with restaurant managers bearing a significant responsibility to mitigate environmental impact and optimize operational efficiency. This study explores four pivotal practices for sustainable waste management: inventory optimization, cultivating an eco-conscious organizational culture, implementing robust recycling initiatives, and embracing composting techniques. From an Islamic standpoint, the principles of responsible consumption and resource management are deeply rooted in the teachings of Islam. The Quran and Hadith emphasize the importance of avoiding waste and extravagance, promoting moderation, and being mindful of environmental stewardship. These principles align closely with sustainable waste management practices advocated in this study. Inventory optimization involves meticulous monitoring of perishable goods, aligning procurement with consumption patterns to minimize waste—a concept consistent with the Islamic principle of moderation (wasatiyyah) and avoiding excess (israf). Restaurant managers, guided by Islamic ethics, play a pivotal role in formulating policies and procedures that encourage responsible resource utilization and waste reduction. Cultivating an eco-conscious organizational culture reflects Islamic teachings on stewardship (khalifah) of the Earth, emphasizing the responsibility to protect and preserve the environment. Encouraging recycling, reusing packaging materials, and promoting eco-friendly practices resonate with Islamic values of sustainability and conservation. Embracing composting techniques aligns with the Islamic concept of tending to the Earth (husn al-khuluq), where believers are encouraged to maintain a balanced and harmonious relationship with nature. Composting represents a proactive step in reducing waste and returning nutrients to the soil, in line with Islamic teachings on responsible resource management. Through a comprehensive sustainability approach rooted in Islamic values, including clear policies, effective leadership, and collaborative efforts, restaurants can contribute significantly to SDG 12: Responsible Consumption and Production. By integrating Islamic principles of moderation, stewardship, and environmental responsibility, this study underscores its relevance in fostering a sustainable environment while promoting sustainable livelihood goals.

Submission ID: 288

Integrating Islamic Teachings with Sustainable Practices: Exploring the Role of Swimming and Hiking in Achieving SDGs 2030

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Abstract

In the pursuit of sustainable development, it is essential to draw upon diverse cultural and religious perspectives to forge meaningful connections between human activity and environmental stewardship. The intersection of Islamic teachings and sustainable practices offers a rich tapestry of values and activities that can contribute significantly to achieving the Sustainable Development Goals (SDGs) by 2030. This research aims to highlight the role of swimming and hiking within Islamic tradition as avenues for fostering sustainable livelihoods and achieving SDGs. In Islam, Prophet Muhammad emphasized the importance of physical activities such as swimming, archery, and horseback riding. These activities were not only seen as exercises for physical strength but also as means of building confidence and resilience. Moreover, historical accounts reveal that mount climbing and hiking were prevalent among the Prophet's companions, serving as crucial activities for physical fitness and spiritual contemplation. As an open water swimmer and hiker myself, I have experienced firsthand the profound connection between these activities and sustainable living. Swimming in open waters instills a deep appreciation for marine ecosystems and underscores the urgency of preserving our oceans. Similarly, hiking amidst mountainous terrain fosters a sense of reverence for nature's beauty while highlighting the importance of biodiversity conservation. Through rigorous research and active engagement with Malaysian respondents, it might be possible to harness the timeless wisdom of Islamic teachings to navigate the complex challenges of the 21st century and safeguard the future of our planet. This research will delve into the practical implications of incorporating Islamic principles of physical activity into sustainability efforts, examining how these activities can be leveraged to promote environmental conservation, community well-being, and sustainable development goals attainment. Through empirical investigation and interviews, this study aims to provide actionable insights for policymakers, educators, and practitioners seeking to integrate cultural and religious perspectives into sustainability initiatives on a global scale.

Submission ID: 292

A Psychospiritual Approach in Dealing with the Stress of Nurses Treating COVID 19 Patients

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Abstract

The work as a nurse in providing treatment to the COVID 19 patients is very challenging. The effect can lead to the psychological well-being of nurses such as stress. Well-being is one of the focuses in the SDG's. Therefore, this paper discusses the stress scenario among nurses who treat patients with the COVID 19. The discussion refers to the results of a study that has been conducted on 353 nurses who were selected as respondents. The research instrument is through a questionnaire that has been developed by the researcher. Among the aspects discussed are the factors, effects and methods of dealing with stress. The results of the descriptive analysis show that the stress factor is the scope of the work (min=2.9671), the main stress effect is the fear of being infected with the COVID-19 (min=3.15) and the treatment method that is often used to deal with stress by nurses is the spiritual approach (min=3.4966) compared to psychology (mean=3.2073). In this study, it is suggested that a psychospiritual approach be implemented to deal with stress among nurses who treat the COVID 19 patients.

10d. Indigenous Systems and Sustainability

Abstracts

Submission ID: 23

Facilitating Regenerative Transformations Towards 'Being in Right Relationships' with the Living: Proposing Generative Questions for Appreciative Inquiry Interviews to Advance 'The Inner Compass' In the Inner Development Goals (IDGs) Framework

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Abstract

Indigenous systems offer a unique perspective on sustainability and regeneration, emerging from a profound understanding of the intricate relationship between humans and the environment. At the core of indigenous cultures lies a way of being in respectful reciprocal relationships with the living. Right relations can then be seen as "an obligation to live up to the responsibilities involved when taking part in a relationship—be it to other humans, other species, the land or the climate". Being in right relationships does then reach into a way of being based on an underlying mindset and awareness. It can therefore be seen as a vital and profound input, inspiration, and foundation for the regenerative transformational change ahead regarding humanity, organizations, and society. The need for such input is also currently stressed within the initiative and framework of inner development goals (IDGs). It is a framework that acknowledges that modern humanity seems to lack the inner capacity to deal with our increasingly complex environment and the challenges connected to caring for and sustaining life on this planet (https://www.innerdevelopmentgoals.org/). In response to that, the IDG framework raises the importance of developing our abilities to relate to and care for others and the world. One of the most foundational shifts highlighted in the IDG framework is the notion of developing our "inner compass", that relates to "having a deeply felt sense of responsibility and commitment to values and purposes relating to the good of the whole". The purpose of this paper is to explore and propose how the development of 'being in right relationship' and the 'inner compass' in the IDG framework might be facilitated by generative questions in appreciative inquiry interview guides. The conceptual paper, focused on exploring and proposing generative questions to be used within Appreciative Inquiry Interviews. It is an approach that acknowledges the power of questions as fundamental for facilitating change. More specifically, when discussing generative questions in relation to appreciative inquiry, research propose that the generativity of the questions increases if: 1) they are surprising; 2) they touch people's heart and spirit; 3) talking about and listening to these stories will build relationships; and 4) the questions force us to look at reality a little differently. As a result, the paper presents a practical output in terms of questions and question guides for appreciative inquiry interviews aimed to facilitate reflection, learning and transformation towards 'being in right relationship' and the 'inner compass' in the IDG framework.

The abstract contributes and relates to leadership development and building capability for continuous improvement and transformation in relation to all of the SDGs. The abstract also relates strongly to the main topic of the conference, as it addresses and elaborates on the destroyed relationship of modern humanity and the notion of sustainability and regeneration as a way of being in right relationship, as practiced by indigenous communities since millennia.

Submission ID: 73

Threaded Sustainability: Unraveling the Handloom Industry's Impact on Gulledgudda and North Karnataka's Socio-Economic Landscape

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Abstract

As the second-largest income-generating activity after agriculture, the handloom sector in India stands out for its minimal environmental footprint, low power consumption, and substantial innovation potential, aligning seamlessly with the global drive towards sustainability. The industry functions decentralized, relying on households as primary production units and operating predominantly in rural areas; despite its economic significance, there is a need for better organization, with the sector drawing strength from the collective expertise and traditional knowledge passed down through generations. There is a need to explore the pivotal role of the handloom industry in shaping India's economy and to delve explicitly into its impact on the socio-economic landscape. The study underscores the robustness of the handloom sector's domestic value chain, connecting locally sourced raw materials to the final product amidst global challenges such as climate change, biodiversity loss, and social justice concerns. Gulledgudda in North Karnataka emerges as a noteworthy case study, exemplifying enduring investment potential due to its rich tradition of craftsmanship. The primary aim is to assess the sector's sustainability and identify opportunities for supporting the weavers' community by adopting circular economy principles. This exploratory research integrates data from structured interviews with weavers and secondary sources. With the handloom industry gaining prominence in global markets, this study contributes an original perspective on sustainable development. Preliminary findings highlight challenges like power loom competition, economic pressures, migration, and limited market access. The study proposes suggestions for aligning traditional practices with circular economy principles to promote sustainable growth in Guledagudda's handloom sector.

Submission ID: 173

Building Bridges: Traditional Wisdom and Sustainable Development in Hill Towns

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Abstract

The traditional knowledge systems of older times were inherently context-specific, tailored to meet the unique demands and needs of specific geographical areas while being responsive to local climates. Serving as a crucial repository of development systems, these traditional practices were passed down from generation to generation. However, the rapid pace of urbanization in hill towns in recent years has led to the erosion of these traditional architectural techniques from society. This phenomenon of rapid urbanization has been associated with various environmental challenges, including the promotion of global warming, the formation of urban heat islands, loss of biodiversity, habitat fragmentation, exploitation of cultural heritage, traditional wisdom and much more. In this context, modern humanity's approach to nature has often been characterized by exploitation, viewing it merely as a means of prosperity rather than recognizing its integral role in livelihood. Governments, acknowledging the urgent need to protect the planet and ensure their continued existence, have adopted Sustainable Development Goals (SDGs) as a framework for addressing these pressing environmental issues. This research paper aims to identify the key environmental problems stemming from rapid urbanization in hills and explore opportunities for solutions by drawing upon traditional wisdom. The methodology employed involves a thorough analysis of environmental challenges through literature study, utilizing qualitative content analysis to formulate a framework of parameters essential for sustainable design in hills. This framework is intended to serve as a valuable tool for a range of stakeholders, including policymakers, community leaders, and organizations, to foster a sustainable environment and promote environmentally conscious decision-making. Additionally, a case study of mud houses in Bhota, Himachal Pradesh, is conducted, involving interviews with local residents to assess the efficacy of traditional techniques. The findings of this study are expected to contribute to the establishment of Sustainable Development Goal Number 11: Sustainable Cities and Communities, by advocating for the integration of traditional knowledge into contemporary urban planning and development practices.

Submission ID: 197

Costs of Coping with Energy Insecurity among First Nations in Northern Canada

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Abstract

Indigenous peoples in the Arctic North of Canada have inhabited these lands for centuries, building cultures of resilience to coexist with the harsh climate. Similar to other 'first peoples' around the world, the communities are built on traditions, knowledge and a well-articulated set of principles governing their relationship with nature and biodiversity. Scholars have identified several factors that constitutes social resilience among indigenous communities. These include age old traditions rooted in their sense of belonging to the place and among people, culture of sharing and passing down generational knowledge, leadership structures founded in trust and shared values, and the ethic of cooperative communal service. Over time, with most sovereign Indigenous cultures and 'nations' becoming subservient to colonial governance structures, the relationships with the two-tiers of institutions and the ability to navigate the gray areas of governance among overlapping structures are additional factors to social resilience.

In this study, we explore how energy insecurity tests and strains the social resilience in one First Nations community in the province of Saskatchewan, Canada. A literature review is first carried out to explore the different ways in which energy insecurity is reported to be experienced in northern remote communities of Canada and in the comparable geography of Alaska. Applying the framework and comparing the relationship between social resilience and energy insecurity at the Deschambault Lake community, we find that coping with uncertain energy systems and their erratic transitions compels indigenous communities to leverage their social resilience capital and capabilities. In some situations, adapting to the uncertainty and erratic energy insecurity strengthens social resilience in terms of increasing the cohesion and willingness to act collectively. However, energy insecurity largely erodes and arrests the long-term value creation capabilities of the community and poses serious challenge to achieving sustainable futures. The persistent strain on household budgets and the burden of negotiating everyday challenges created by energy insecurity on community governance arrests their ability to imagine, plan and advocate for long term solutions. The traditional knowledge networks and culture is strained by the decline of spaces and opportunities to socialize, as such spaces have now been locked into a reliable supply of electricity. Declining practice of wood harvesting skills and opportunities has made the community more dependent on imported fuels, signaling the social risks of lowered diversity of energy resources.

We conclude that slow and indecisive energy transitions is giving rise to a period of increased social vulnerability and strained social resilience in northern Indigenous communities of Canada, which is causing significant harm to their long-term potential to achieve sustainable futures. The findings offer urgent advice to address this 'in-between' challenge in the pursuit of all 17 SDG's and targets, where an explicit acknowledgement of Indigenous people in Arctic regions is a glaring gap. This is relevant to the Himalayan context as well, which shares many of the socio-cultural and geophysical features with the Arctic.

Submission ID: 283

Renewable Energy Technologies and Local Communities: A Case Study of Brumadinho, Brazil

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Abstract

The manuscript takes as a contextual refinement the governance process about renewable energy for the municipality of Brumadinho, in the state of Minas Gerais, Brazil, a territory historically marked by mining activity. At the territory, certain local groups show limited access to electricity, and the state energy supply company – CEMIG – assumes that availability is unstable and has limitations, reinforcing the search for answers regarding alternative energy availability.

Since 2019, the "Mina Córrego do Feijão" dam disaster has had impacts on the population with a direct relationship to the cultural, environmental, and socioeconomic dynamics of the municipality. The episode was responsible for the deaths of two hundred and seventy-two people and spread ore residue throughout the "Paraopeba River" basin. What researchers classify as a stage of overcoming mining dependence (post-tragedy), for the groups studied, refers directly to rights violations, loss of memories, death of close ones, and a daily life surrounded by challenges.

The manuscript seeks to discuss and analyze, in the face of insecurity in electricity in the region, possibilities for promoting actions by public entities, the framework of public policies, and the search for solutions on the renewable energy agenda. It is in the wake of the process of reparations for the mining sludge disaster, in compliance with the commitments made by Brazil in international forums and within concerns about climate change and the energy future that this investigation is positioned.

Traditional communities ("quilombola" and indigenous territories) and associations of recyclable collectors make up the groups researched. The action research model (planning-reflection-action) is the one that best suits the context of these groups as it provides space for the exercise of independence, self-determination, citizenship, and self-management capacity. Qualitative research, of an exploratory nature and with participant observation, defines the conditions identified as necessary for a better understanding of the facts presented. The methods and techniques employed include field visits, research diaries, and semi-structured interviews.

To date, it is possible to recognize advances in bringing researchers closer to the way of life of those being researched, the recognition of perennial conflicts in the repair process, the scenario of insecurity in electrical energy for the groups in question, as well as the emergence of social innovations/technologies that unfold by bringing, in the post-tragedy context, new directions for the lives of residents.

Submission ID: 313

A Global Climate Niche for Grazing

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Abstract

Grazing systems are critical arenas where intersections of climate change, food security, and welfare of impoverished populations converge. Future climate change will impact grazing practices, which will, in turn, further influence the broader climate dynamics. However, the specifics of how these interactions will unfold on a global level remain poorly understood. Here we approach this complex problem from a fresh perspective by defining a climate niche for grazing as an entry point to a comprehensive perspective on these complex relationships. We leverage extensive datasets and computational simulations to identify a "grazing niche" (GN) where climatic conditions historically favor pastoralism, demarcated through the analysis of millennia-long climate and grazing data. In our paper, we yield three principal insights. First, we characterize and identify suitable areas for livestock grazing, as defined by "grazing niche', and find they are only a small subset of today's vast grassland resources. The second major finding of our study is that a significant portion of present grassland-based livestock has shifted away from the historically identified climate niche and has concentrated in regions with high dietary demand or scarce alternative options for economic production, leading to large-scale overshooting of grassland capacity both within GN areas and outside GN areas. Finally, we show that the future GN area will face a continental shift under different RCP scenarios in 2100. Presently arid regions in Asia such as the Turan Plain would be enveloped as a principal reservoir for niche grassland, while Europe, Africa, and Himalayas' usable grassland reservoirs will significantly decrease by 2100. Our research presents complementary views to the existing traditional research taking the course of examining plant species composition, soil properties, animal physiology, etc., and turning towards big data simulations by taking advantage of the available millennia-long historical dataset and future projections of climate and land data, attempting at probing the connections between climate change, human activity, and grassland changes. Through these analyses, we hope to offer a renewed perspective on an enduring, yet increasingly precarious, form of indigenous subsistence and its role within the global climate discourse.

This research is within the scope of 10d "Indigenous systems and sustainability" and corresponds to SDGs 1,2,3,10,13, and 15.

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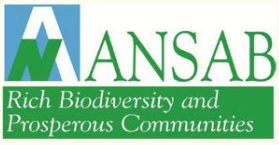
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