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The transition from a "city of waste" to a "circular city": virtuous practices in the city of Pavia

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Abstract

Cities are facing the greatest challenge of their whole lifecycle: choosing their own destiny. Cities are the main contributors to climate change, as much of the excess carbon dioxide in the atmosphere comes from them. Understanding how cities can transform into "circular cities" is key to fostering change. However, empirical studies in this direction are still scant. In this paper, we address this research gap by answering the following research question: how are current "cities of waste" transitioning to "circular cities"? We do so by means of an empirical study involving several stakeholders located in the town of Pavia (Northern Italy). We find that some actors have implemented virtuous circular economy (CE) practices; however, the transition to CE is overall conducted in a fragmented manner, with a lack of orchestration and planning among private actors as well as a lack of synergies between private and public actors. We conclude our study by advancing future avenues of research, highlighting our theoretical and managerial contributions, and advancing policy implications.

Keywords: Smart cities; Circular cities; Circular economy; Focus group

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1. Introduction

Cities are major contributors to climate change. According to UN Habitat, cities consume 78% of the world's energy and produce more than 60% of greenhouse gas emissions. However, they account for less than 2% of the Earth's surface. The phenomenon of urbanization is massive: approximately 66% of the world's population will live in cities by 2050 (United Nations, 2014). In Europe, urban areas are home to more than 75% of the population, they account for 80% of energy use and generate 85% of the European GDP (European Commission). Due to the significant influence cities have on climate change, it is imperative that they expedite their shift toward sustainable and circular approaches, by embarking on serious paths of change in the use of natural resources as well as in their citizens' consumption practices. For instance, cities are considered fundamental actors in tackling food waste, as they can actively introduce adequate policies, initiatives, and projects to reduce it (Fattibene et al., 2020).

Cities are essential for Europe's transformation to a climate-neutral continent by 2050, as set out in the European Green Deal (Eurocoties, 2020). A shift toward more sustainable cities is urgently needed. The Ellen MacArthur Foundation highlights that cities have a high concentration of resources, capital, data, and talent spread over a relatively small geographic area and are also centers for innovation. This means that cities are uniquely positioned to drive a global transition toward a circular economy (CE) (Williams, 2021).

The CE aims at preserving raw materials in a permanent loop to maximize the employment of resources. The result should be the reduction of waste. Different cities, according to their characteristics, adopt different kinds of CE practices thus opening multiple scenarios. A circular city is defined as "a city that practices CE principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business, and knowledge stakeholders), to realize its vision of a future-proof city" (Prendeville et al., 2018). Circular cities are praised for their commitment to implementing practices aimed at reducing the overall urban emissions. However, the concept of a "circular city" is still in its emerging phase and it thus appears a slightly blurred and utopian, especially because of the lack of empirical evidence as there is not a single model to be followed, but rather more models advancing concrete circular practices to be adopted at the urban level.

In this paper, we aim to fill this research gap by empirically investigating how a "city of waste" whose activities are rooted in the linear "take-make-dispose" paradigm could shift toward a "circular city" by means of virtuous sustainable practices implemented by different stakeholders. The addressed research question is "how are current "cities of waste" are transitioning to "circular cities"?

Our research context is an Italian middle-sized city, Pavia (Northern Italy). Pavia is home to one of the most ancient universities in Italy. The University of Pavia is part of the EC2U (European Campus of City-Universities) consortium, which includes six other European universities: the University of Coimbra (Portugal), Alexandru Ioan Cuza University of Iasi (Romania), the University of Jena (Germany), the University of Poitiers (France - coordinator), the University of Salamanca (Spain), and the University of Turku (Finland). The EC2U consortium aims at creating a pan-European campus, with a shared governance model, fostering mobility within the seven universities and developing innovative models in education, research, public engagement and third mission. One of the tools adopted by this European project is the organization of Think Tanks, policy institutes promoting debate on research topics relevant for the social and political context to implement ameliorative strategies.

As part of the EC2U alliance, one of the promoted Think Tanks focused on the circular economy - Key to Change and Sustainability - organized in Pavia in February 2022. Through three focus groups, involving multiple stakeholders of Pavia who have been proactive in developing circular practices, we unveil the challenges they faced/are facing in implementing these practices, we explain how they tackled them, and illustrate the remaining issues to be solved. With our study, we contribute to the academic literature on urban studies by providing empirical evidence of circular practices implemented by different stakeholders in a specific Italian urban context. We also contribute to policy-making by advancing policy suggestions stemming from our findings.

The remainder of this paper is structured as follows. First, we introduce the background literature on urban studies about smart and circular cities. Second, we illustrate the methodology employed and we discuss our findings. Finally, we highlight our theoretical and managerial contribution, and we propose future research avenues, some of which will be deepened also in another project of which the University of Pavia is a partner, funded by the European Union - Next Generation EU, within the Italian National Recovery and Resilience Plan, on "Research and Innovation for Sustainable Food and Nutrition - ONFOODS".

2. Theoretical background

The development model based on the massive consumption of natural resources is showing all its fragilities and implications at the global level. The European Green Deal calls for a zero carbon Europe by 2050 (Piontek et al., 2021). To do so, the introduction of accurate measurements for organizations' circularity is necessary (Vola et al., 2023). Cities, for more than a century, have been the driving force behind the development of nations, but the industrial model on which they have based their fortunes, wealth and success has generated social and environmental costs whose effects are showing themselves in full magnitude from year to year. Starting from the end of the 20th century, the debate among urban planners and city scholars about the need to imagine a different future for the cities of the world has led to the development of the "smart city" paradigm, a new way of understanding the functioning of urban systems based above all on the contribution of digital technologies. The smart city concept turns out to be an evolution of the paradigm popularized in the early 1990s of the "digital city" (Couclelis, 2004; Hepworth, 1990). Subsequently, the smart city idea coincided with the urban development model of an "entrepreneurial city" as a style of urban governance based on global competition, financialization of urban space through urban regeneration and culture (Mahizhnan, 1999).

Only recently, with the growing concern about the impact of climate change on the fate of cities, has the connection between smart cities and environmental sustainability made its way (Caragliu et al., 2011). The urban planning paradigm of the smart city has occupied urban agendas for several years and represents an idea of the city that, too often, has been embraced uncritically. The promise of this way of understanding the cities of the future lies in collective advantage in all respects, social well-being, environmental sustainability, and a harmonious urban environment. Although there is no agreement on one definition of a "smart city" (Komninos & Mora, 2018), there is a consensus on the fact that a smart city involves development and improvement (Guenduez & Mergel, 2022), to solve urban challenges and improve the quality of life (Nicolas et al., 2020). It is a model of a city that has shown strengths and deep weaknesses, especially in the environmental and social dimension (Evans et al., 2019). It can be said that the "smart city" model is even still today an ideal type to potentially strive for, but one that is far from being achievable in the current state within which contemporary developed cities move. The literature is replete with such criticisms, such as the case of Datta (2015) who argues that the concept of a "smart city" is nothing more than "the utopia of the 21st century". Other authors glimpse within the "smart city" paradigm a new way of understanding the transformation of contemporary cities, no longer driven by political and social ends, but predominantly industrial and neoliberal (Haarstad, 2017). Przeybilovicz et al. (2022) highlight the key role of citizens in promoting initiatives to improve the smart city and in taking part in its governance (Meijer and Bolívar, 2016; Webster and Leleux, 2018). Angelidou et al (2022) argue that scenarios for future urban development need to consider smart cities, smart transport, and smart energy as strictly interconnected.

On the one hand, urban governments have seized the opportunity of the spread of the "smart city" paradigm to implement policies aimed at attracting capital to cities, which has been subject to criticism (Martin et al., 2018), on the other hand, the environmental sustainability component has been recently emphasized in the literature (Haarstad, 2017; Bibri & Krogstie, 2017). The challenges of decarbonization and mitigating the impacts of global warming in cities are stimulating research and theoretical reflection, particularly in the field of industrial economics. This involves exploring the possibility that the production processes of goods and services, partly responsible for global warming, can transform their practices and shift toward a circular economic model that might lead to the establishment of "circular cities" (Williams, 2021; Vanhuyse et al., 2021). We refer to the idea of economic models under the circular economy umbrella, which are finding strong points of contact with the smart city paradigm (Dincă et al., 2022).

Circular economy (CE) could be defined as "an industrial economy that is restorative or regenerative by intention and design" (Ellen MacArthur Foundation, 2013, p. 7). CE can be a path toward more sustainable ways of living (Borrello et al., 2017), since it provides clear directions on how to narrow, slow, and close the resource loops (Geissdoerfer et al., 2017), aiming to reach sustainable modes of production and consumption (Bocken et al., 2018; Ghisellini et al., 2016). To better address today's challenges and remain attractive for their stakeholders, cities are developing reliable and sustainable solutions (De Jong et al., 2015; Neirotti et al., 2014; Yigitcanlar, 2011). The CE can thus represent a concrete response to mitigate the impact that cities have on the environment, and its relevance for cities and urban planning is being increasingly reflected in the literature (Bolger & Doyon, 2019; Brzica, 2023).

By integrating the concept of CE into urban studies, some authors (Bolger & Doyon, 2019; Prendeville et al., 2018; Williams, 2019) have recently introduced the concept of "circular city". Prendeville et al. (2018) highlight that there is a lack of consensus

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on what a circular city is and about the how and why of the circular city concept. The authors offer a conceptualization of a circular city as "a city that practices CE principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realize its vision of a future-proof city" (p. 187). Bolger and Doyon (2019) analyze the role of local governments in promoting CE initiatives through strategic planning. By means of a comparative study conducted in Melbourne and Malmö, the authors show that municipalities make considerable efforts to improve resource management and recycling practices. Nevertheless, the level of consumption in both cities remains high and therefore the authors argue that a change in consumption patterns needs to be further promoted at a public level. Ghisellini et al. (2016) support the idea that local governments (municipalities) have great potential for supporting the transition toward sustainable development. Williams (2019) argues that the RESOLVE framework of the circular economy (Ellen MacArthur Foundation, 2015), which includes six actions to move toward a CE (Lewandowski, 2016) is inadequate when applied to the context of the city. The author advances instead the idea that implementing circular economy principles at the city level requires the regeneration and renewal of complex urban ecosystems. Studies regarding circular cities are in the early years, and those conducted in the Italian context are a few (Benedetti et al., 2022; Ghisellini et al., 2022). Benedetti et al. (2022) focus on the construction sector and they study urban regeneration by comparing demolition with reconstruction and renovation in the city of Bologna. Ghisellini et al. (2022) investigate pioneering CE practices implemented in the city of Naples, which currently lacks a vision of a circular city, and they offer new insights regarding opportunities for transition toward CE.

3. Methodology

In this paper, we aim to contribute to the growing urban studies investigating circular cities by providing empirical evidence of circular practices that may facilitate the transition from a "city of waste" toward a "circular city".

3.1 Focus group

The focus group is a research methodology that is increasingly adopted in diverse research contexts and fields (Morgan, 1996). A focus group is defined as "a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research" (Powell & Single, 1996, p. 499). Focus groups are interactional by nature and allow the participants to exchange ideas and opinions. As the aim of focus groups is to maximize the interactions among participants, having smaller groups is preferred, to offer more opportunities for participation in the discussion. Wilkerson (1996) argues, however, that groups may be smaller. Wilkerson (1996) proposes five as the optimal number of participants and argues that the maximum number of participants may be eight. By following these recommendations, the number of participants in each focus group is equal to six.

3.2 Research setting: Pavia

Pavia is a mid-sized city of approximately 70,000 inhabitants, located in Lombardy, close to the Ticino River. It is home to a university founded in the 14th-century, one of the most ancient in Italy, and it hosts the San Matteo Hospital, one of the most important hospitals in Italy.

We choose Pavia as a research setting as this study stems from a wider project we conducted within a European consortium, EC2U (European Campus of City-Universities), of which Pavia, as the sole Italian city, is part. The consortium's objective is to foster research, education and multistakeholder dialog throughout the seven member universities and European communities. One of the key formats that has been developed by the alliance is the Think Tank, which aims at bringing citizens, scientists, and policy makers together to discuss and share best practices. In 2022, the Think Tank was centered specifically on CE. Each of the seven EC2U partners conducted its own local Think Tank on the topic (EC2U 2022). All local findings were then presented and discussed in a joint session during the 4th EC2U Forum in Pavia. As a result, a set of policy recommendations has been agreed upon.

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The Think Tank in Pavia has been structured into three focus groups to elicit the debate among diverse groups of stakeholders located in Pavia. These stakeholders are pioneering the implementation of circular practices as part of their business models (e.g., sustainable mobility, recycling, sustainable nutrition). Thanks to the project, it was possible to bring together different actors of the city of Pavia and let them interact and exchange opinions and ideas.

3.3 Data collection

In February 2022, an online meeting via Zoom on the topic of adoption of CE in the city of Pavia was organized. The structure of the symposium foresaw three focus groups involving stakeholders grouped into three main categories: 1. Universities; 2, Firms; 3. Other associations/projects.

We proceeded to select stakeholders that could meet our research objective by adopting a purposeful selection criterion (Patton, 2015), so that i) stakeholders were needed to be local, meaning based in Pavia or in the nearby and ii) to have implemented circular practices. By following these criteria, twelve stakeholders per each of the mentioned stakeholder group (N=36 stakeholders) were selected and emailed to check the availability of an internal knowledgeable informant to take part in the focus group. We obtained the consensus of six stakeholders per each group (N= 18 stakeholders). Our final sample is composed of eighteen stakeholders (Table 1).

Table 1: Focus group participants

GROUP 1: University	**GROUP 2: Firms**	**GROUP 3: Other associations/projects**
UNIPV, Mobility Manager	VoltaPlant - alternative energy, startup	Fiab (Federazione Nazionale Ambiente e Bicicletta) - environmental organization promoting the daily use of bicycles and cycle tourism
Italbiotec, waste consortium	Planeat - online platform for grocery shopping starting from recipes and buying ready-to-use fresh and organic ingredients, benefit company	Fondazione Banco Alimentare ONLUS - not-for-profit association aiming at collecting food waste and distributing it to charitable associations
Ghislieri College	BioRestart - start-up, production of substances from plant waste and bio products	Giulia Marrazzo - expert in active citizenship
Borromeo College	LavGon - ethical fashion laboratory, creative and craft shop	Il Sellino Spiritato - Association of citizens of Pavia aiming to promote the bike use
UNIPV, OSA Office for Sustainable Actions	FungoBox and Coffeefrom - social enterprise aiming to develop a sustainable urban agriculture starting from coffee grounds	Re-Cig - start-up having the mission to collect and recycle cigarettes' filters to make objects through a patented process
ESN - Erasmus Students Network, President	Assolombarda - Industrial Association of the territories of Milan, Lodi, Monza and Brianza, Pavia.	Repair Café Pavia - group of volunteers devoted to repairing broken items

Source: Author´s elaboration

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The round table discussion among the stakeholders revolved around the motivations to develop circular practices, the specific problems and challenges faced, and the implemented solutions to overcome them. More specifically, the questions we asked during the focus groups were the following:

1. **Motivation**: What motivates the stakeholders to engage in a circular economy?
2. **Problems**: What are the specific problems and challenges that the stakeholders have attempted to solve?
3. **Solutions**: Which solutions did the stakeholders come up with and implement? What helped rather than what hindered them along the way?
4. **Remaining Challenges**: What are the next challenges that the stakeholders want to tackle/or: what are the problems that they yet must solve?

3.4 Data analysis

Each focus group lasted 120 minutes, it was recorded through Zoom, and was transcribed within 24 hours. All the interviews were performed in Italian and then translated into English after the transcription. To ensure internal validity, we triangulated primary data with secondary data (web and journal articles, the press, and social media pages) (Denzin, 1978). We also relied on investigator triangulation: we compared the data analysis within our research team until reaching a shared agreement (ibid).

To analyze the data, we manually coded the participants' sentences by using different colors, to classify them into the considered variables of interest: i) motivation to start circular activities, ii) area/topic of implementation, iii) challenges, iv) solutions to be implemented, and v) other problems

4. Results

Here, we introduce the results stemming from each focus group, by presenting tables of results that include five variables, i) motivations to adopt CE practices, ii) area/topic of implementation, iii) challenges faced, iv) solutions found, and v) remaining problems (Table 2).

Table 2: Focus group with stakeholder: university

Group 1	Motivations	Area/Topic	Challenges	Solutions	Remaining problems
University of Pavia, Mobility Manager	-Reducing the use of private vehicles -Overall contribution to the reduction of CO2 emissions.	Sustainability in the mobility/transport area (increase of use of public transport, reduction of parking slots, fostering use of bicycles)	Engage local actors (e.g. hospitals, municipality), that employ many inhabitants and have an impact upon the commuters	More engagement activities and greater involvement of other local actors to establish synergies with.	Coordination and cooperation with other local stakeholders
Italbiotec	-Reducing waste -Defining a common framework regarding the concepts linked to the CE	Innovation and dissemination in the local area and engagement of the civil society	-Technological challenges (Research & Development) -Attract investments, common	-Increase the moments of interaction with the territory; -Foster the communication with actors having	-Defining a "common language": being able to disseminate the topic of innovation in a way that is understandable for the general public -Ensuring an overall

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			understanding of "different languages"	different background	understanding of sustainability (overcoming the difficulty in understanding the intersection between the three aspects of sustainability, i.e., economic, social, and environmental)
Ghislieri College	-Increase the educational offer in the College, students' awareness, students' proactivity, and develop international synergies on the topic. - Increase the Research on sustainable agriculture via the College's rural plots of lands.	Nexus of: Environmental sustainability - Health - Enterprise. Sustainable agriculture.	-Ensure a common framework, raising awareness about the topic of sustainable agriculture. Challenges are linked to research capabilities.	-Develop mandatory courses to ensure that all students are homogeneously trained on the topic of sustainability.	N/A
Borromeo College	-Reduction in consumption of: plastic, CO2 (energy), cards. -Careful waste sorting/recycling	-Waste and food waste, energy. - Biodiversity and natural heritage.	-Heritage preservation as a key value to be conveyed to students. -Transversality of sustainability values.	-Fostering information/dissemination. -Direct involvement in activities of training and information, to enable a process in "cascade": students as ambassadors outside the academic field.	-Reaching out to the public with information and dissemination activities. - Lack of an integrated communication which would be able to create a bridge between research and society.
OSA - Office for Sustainable Actions	-Creating synergies among all departments and offices of the university -Spreading the transversality of sustainability.	-Education -Waste reduction -Energy efficiency -Valorization of the green heritage	Difficulties in collaborating with external actors, and often with internal actors of the university itself.	Expand and foster communication.	Lack of collaboration and specifically in the waste sector: waste quantification and management problem with external actors.
ESN - Erasmus Students Network	Increased students' awareness and engagement.	-Waste reduction (via garbage collection); - Second-hand	Lack in active participation of local actors.	-Bottom-up involvement, starting from small local actors	Reluctance to active participation.

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		clothing collection; awareness raising activities (e.g. conferences).		(e.g., Plastic Free) and development of synergies with the University -Increased awareness to fight indifference and reluctance to get involved.	

Source: Author´s elaboration

All the actors taking part in this focus group are colleges and networks aiming to develop sustainable actions. The common issues these actors face regard the engagement of local actors, the lack of a "common language" that prevents stakeholders and civil society from interacting fruitfully, and the overall lack of proactivity and collaboration among actors (Table 3).

Some main solutions that have been implemented to tackle these issues are the dissemination activities, and an increase in the communication and involvement of local actors.

Table 3: Focus group with stakeholder "*firms*"

Group 2	Motivations WHY	Area/Topic	Challenges	Solutions	Remaining problems
VoltaPlant	Removing battery by substituting the energy stemming from plants	Power improvement for lighting systems and IOT, new materials	-Carbon offset -Produce a sufficient quantity of energy	Select and implement new materials that are increasingly recyclable and sustainable	Further raise the performance of these cells to obtain maximum operating stability and repeatability of the cells
LAVGON	Develop an alternative, ethically and socially responsible way to produce garments (handicraft laboratory)	High quality raw material, rethinking and reuse of fabric/textile scraps	-Communicate the value proposition to prospect clients -Finding manufacturers suitable for processing textile waste -production into a system of suppliers and a reuse network (not only textiles)	Create a network of informal suppliers and local associations interested in processing textile waste	-Communicate the value proposition to the clients -Find the proper suppliers having recyclable/sustainable inputs at affordable prices

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Biorestart	Use waste from the agri-food chain to extract bioactive compounds	Organic waste recovery	Scaling-up and decreasing the environmental and economic impact of the waste transportation	Building waste treatment centers through Italy	Decrease the water consumption needed for the process through water recovery
Planeat	-Provide to as many people as possible a sustainable alternative to the traditional grocery shopping -Fighting food waste	Tool for healthy meals planning	-Fight food waste and disposable plastic -Finding the proper suppliers providing sustainable materials -Economic sustainability	Development of the Planeat.com platform to implement a new grocery shopping concept	-Scaling-up -Competition of the large-scale distribution
FungoBox and Coffeefrom	Reuse the coffee grounds as a production input	-Kits to develop a bio-based material from recycled coffee grounds and biopolymers - Zero-waste alternative to traditional plastic	-Develop more versions of the coffee granules by increasing the % of recycled coffee grounds -New applications of the material and new partners	-Finding an increasing number of practical applications - Finding partnering firms aiming to substitute the traditional plastic with a Coffee from product	-Encourage producers to embrace the circular paradigm -Stimulate investments to foster the circular economy
Assolombarda	Role of wrap up - proposing synergies and joint projects				

Source: Author´s elaboration

All the actors taking part in this focus group are local startups and firms adopting a sustainable or circular business model since their foundation: they all aim to make a positive impact on the environment by implementing business-based solutions to reduce waste. Apart from specific challenges concerning the developed products/services, the firms have common issues to be faced concerning the scalability of their business, the achievement of economic sustainability and the development of industrial symbiosis. Some solutions to overcome these issues have already been implemented, i.e., the development of informal networks and the establishment of partnerships with other firms. Assolombarda, being the most important association of the Italian entrepreneurial system in the country, may assume an active role in fostering the transition toward circularity, by advancing guidelines in terms of circular practices, and enhancing synergies between economic actors (Table 4).

However, several are the difficulties that remain and still need to find a solution, i.e., scaling-up and building full circular value chains since investments and partners are frequently not available or are difficult to identify.

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Table 4: Focus group with stakeholder "*local associations*"

Group 3	Motivations WHY	Area/Topic	Challenges	Solutions	Remaining problems
Active Citizenship (Cittadinanza attiva)	Spreading a culture that can influence waste practices by transforming them into education of reuse, recycle and repair, or to virtuous purchasing practices (buying food in bulk, etc.).	Spreading among citizens the culture of reuse, recycle and repair.	Involve as much citizenship as possible.	Eco-tour in the center of Pavia to discover stores where you can buy loose, eco-sustainable and Km 0 products, repair or borrow objects etc.	Increasingly implement initiatives that help influence the acquisition of virtuous practices of pro-environmental/sustainable behaviors.
Il sellino spiritato	-Study mobility plans for several cities including Pavia -Democratizing the public space making the urban mobility more sustainable.	Spreading a culture of sustainable urban mobility.	Enhancing the collaboration with public and private actors in order to reach a general impact on the urban mobility of Pavia.	Cycling tracks could be improved at 7% with small and cheap interventions (e.g. changing vertical signage).	-In Pavia every hour 5.000 cars travel less than 3 km; respiratory pathologies increase and the pedestrians still have a small amount of public space to walk on. - Investors should be more involved in the whole planning process.
Re-Cig	Re-Cig deals with the collection and recycle of cigarette butts, with a patented process	It proposes a service to companies to collect the butts in compliance with regulatory standards (Smokers Point), including the use of a portable ashtray and the transportation of the waste to the recycling premise	Circularity is the main objective starting from a waste that had no previous reutilization practice, even though the material deriving from the recycling process is at the moment poor in quality and limited in quantity	Reduce waste by extending the collection of cigarette butts in larger areas and recycle the butts' main components to re-market it as a component for other products (useful in the production of glasses)	-The legal framework is still very complicated even if there are signs of recent re-considering strategies by policy makers (including the amendments of the Italian Constitution) - Try to involve cigarette producers to adopt policies or reduction of butt waste and pay for the recycle

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Fiab	Strong contribution in spreading the culture of soft mobility in order to achieve a multidimensional impact on both mobility practices and urban environmental quality.	Spreading the soft mobility practices	Make an effort not only to facilitate the transition to sustainable mobility, but also (indirectly) to make the city more livable, beautiful and with a higher quality of life.	The University should take greater responsibility in being a driver to urge the spread of cycling in the city. In this sense, the University can play a role in lobbying the City Council to take concrete steps to improve urban mobility.	FIAB is active in proposing concrete solutions to promote sustainable mobility, but more resolution is needed from the public actor in implementing these projects.
Banco Alimentare	Collect foodstuffs which are still perfectly edible but, having lost their commercial value or being unfit for sale (consisting of surplus production, incorrectly labeled products, food close to its 'use-by-date', food leftovers and surplus from catering and canteen services) would be destined to landfill. The main supplying sources are food industry, organized large-scale retail trade, and collective catering service.	Food surplus is prevented from becoming waste, thus recovered as a resource for those who cannot afford edible and nutritious food. -Participation with other stakeholders and policy makers to frame both new legislation (internally, the so called 'Gadda' Law enacted in 2016) and common guidelines (i.e., the Manual of Good Practices for Charitable NGOs) to help private donors and nonprofit charitable organizations in donating, recovering, collecting, storing and distributing food for charitable purposes to people in need, while assuring	-Recovering food surplus and leftovers to redistribute them for free to the increasing part of the population in need living in the city which the market and public services cannot reach. - reduction of the environmental impact of food production and consumption on climate changes as it reduces the carbon footprint related to cities. - educating people on the importance of giving value to food avoiding waste, as well as of raising awareness around the themes of food poverty, healthy diets and volunteering in the cities.	-Donation of safe food surplus should become a practice to be more widely spread through the entire food chain, from the production to the retailers and consumption level. - Every year Banco organizes the National Food Collection Day, involving a large network of supermarkets and civil society and raising awareness about the problem of food poverty thanks to a concrete and free gesture of sharing. - launching the 'Siticibo' initiative, a network aimed at recovering large scale retailers and catering surplus.	-A uniform definition of parameters to measure food waste volumes at the local, European and international levels, is still missing, thus threatening the common efforts made to modify the relevant existing legislation in an effective way -The donation dimension should be added to the traditional 3R cycle

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		food safety and traceability.			
Repair Café	Reduce the waste created by those who throw away without first attempting to repair the seemingly no-longer-functioning object for its original purpose.	Teaching how to repair or reuse for a different purpose daily life objects.	Fighting the "consumption & waste" culture convincing people to repair and reuse instead of wasting used objects requires time.	The project is completely based on training sessions and workshops to spread this culture of repair and reuse.	-There are no right tools to access that product or to repair it -It would be necessary to change the law so that manufacturers would be responsible for making items produced reusable.

Source: Author´s elaboration

All the actors taking part in this focus group are local associations/projects aiming to promote sustainable and circular practices in the fields of urban waste, mobility, and food. The common issues these entities need to face concern the low level of collaboration and engagement of public actors and the complexity of dealing with the current legal framework and the complex bureaucracy. We find that some key solutions that have been implemented to solve these problems are networking with the public and private sector, looking for a higher visibility by interacting with the university (useful for lobbying at different levels, from local to European level). Finally, a pattern can be found along all the outcomes of the focus group, that is the need for a more effective involvement of the public institutions of the city. Indeed, the transition from a city of waste to a circular city can become feasible thanks to the collaboration with all the stakeholders of the urban society who actively participate in this social process.

5. Discussion

The conducted analysis of the focus groups allows us to identify six virtuous circular practices to transit from a "city of waste" to a "circular city" .

First, the implementation of circular business models within some urban economic activities. This is a positive sign as it means that Pavia is showcasing trends of transition from traditional linear business models to new circular approaches. Obviously, the spread of this model among the city's economic actors is not yet pervasive, but the presented cases offer signals that testify a occurring within the local system.

Second, we observe the will to prevent/reduce food waste through several businesses and organizations dedicated to promoting the circularity in the food field. As cities have a key role in tackling food waste (Fattibene et al., 2020), we deem that the implementation of these virtuous circular food practices is crucial within a "circular city".

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A third practice emerging from the focus groups regards the promotion of a sustainable mobility. Circularity, having a primary goal focused on environmental sustainability, inevitably involves the world of transportation and its impact on air quality. Pavia showcases some active players in the association sector, who carry out several activities to downsize local private motor transportation, and facilitate bicycle transportation instead. In this case, interaction with the public body becomes crucial to implement the various bicycle-pedestrian projects.

The spread of circular economy practices, however, seems to involve not only the strictly business-related field, but also the association sector, which is the fourth factor. In particular, the focus group reveals the strong role played by some actors in the field of "Reuse-Reduce-Recycle" practices. The presence of these actors in the urban context shows how circularity is a paradigm that cannot involve only companies; rather, it should engage all members of a society and stimulate social activism.

A fifth virtuous practice emerging from the focus group concerns collaboration between university and stakeholders. The University of Pavia constitutes a historical institution for the city, due to its educational role and related to scientific research. Universities represent key resources for cities, as key drivers for technological experimentation and for the study of practices that can be implemented in policy making. Collaboration between universities, local government and, more generally, all stakeholders active in the circular economy process, makes it possible to trigger those innovation processes that are fundamental to truly progress in the transition from “a city of waste” to a “circular city”.

Finally, a sixth virtuous practice concerns the involvement of the citizenry to spread sustainable behaviors. Again, the role of associations is crucial in implementing activities to spread circular behaviors. In the focus group, for example, various activities have been presented by participants (e.g., workshops aimed at teaching stakeholders how to repair objects and make them usable again, plastic collection days, bike repair stands).

The empirical evidence thus shows that there are some fundamental "ingredients" in a city to create the social conditions for actions and initiatives attributable to the circular economy sector to be activated. The six identified virtuous practices could be the basis for a future evaluation of a city circularity, as already proposed by Vola et al. (2023) with respect to organizations’ circularity.

Finally, while the study by Vanhuyse et al. (2021) highlights the lack of social impact considerations in research about circular cities, through our empirical study we can find some hints about social activities that are embedded in business models (e.g., CSR activities, social inclusion) or are part of an actor’s mission (e.g., education about sustainability). The University of Pavia, as a relevant historical university, may represent a key actor in fostering the social aspects linked to CE, in addition to its commitment in the third mission and the public engagement (which is supported by the creation of important structures such as the Office of Sustainability). However, all these territorial and university activities work in a fragmented and disconnected manner, lacking a solid and extensive network allowing continuous exchanges and favoring the connection between the several and diverse territorial experiences. In particular, the difficulties in interaction between the local government and the economic actors prevent the unleashing of the full potential of all these CE practices leading to the construction of the smart city of the future. While private and public actors often diverge in their objectives, greater collaboration between circular economy actors and the local government becomes crucial to enable the dissemination of the benefits of this approach to economic production throughout the urban community. The literature is beginning to highlight these effects (Dagilienè et al., 2018; Wasserbaur et al., 2022; Christensen, 2021), where private entrepreneurship is facilitated by political actions capable of supporting it and enabling the release of its potential positive impact on the urban community.

In the case of Pavia, therefore, it seems necessary to cultivate greater interaction both among the actors involved in the field of circular economy (especially business ventures and local associations) and between them and the public actors - University included - to develop a virtuous relationship that provides real support to initiatives beneficial for all stakeholders involved.

If Williams (2019) supported the idea that implementing CE principles at the city level requires regenerating the urban ecosystem, thus going beyond the RESOLVE framework, we find little evidence of environmentally regenerating activities in our analyzed city, and they are mainly bound to the sustainable mobility. Raising awareness regarding CE and increasing investments in urban regeneration should be priorities of the next decades. Our findings add to the study of Bolger and Doyon that public actors need to assume a leading role in facilitating and orchestrating the network of different stakeholders operating locally in order to transform a “city of waste” into a “circular city”. Finally, we also find that the potential of local municipalities in favoring the transition toward circular cities (Ghisellini et al., 2016) still needs to be fully exploited in the analyzed city.

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5. Conclusion

This paper aimed to contribute to the emerging literature of urban studies about circular cities (Benedetti et al., 2022; Ghisellini, 2022; Prendeville, 2019; Williams, 2019) through an empirical study aimed at investigating virtuous practices of transition toward a circular city. Thanks to three focus groups conducted within the EC2U Think Tank in the city of Pavia (northern Italy), we could identify virtuous practices to transit from a "city of waste" towards a "circular city", i.e., circular business models by local firms and NGOs, reducing of food waste, promoting sustainable mobility, local activism focused on "repairing-reuse-recycle", collaboration between the university and private stakeholders, and civic engagement for improving sustainable behaviors. All these outcomes give an account of the presence of a background in the city of Pavia that could gradually enable the good conditions to build a city aware of the relevancy of the circular economy.

Our case study suggests that cities have many possibilities to shift toward a circular economy, by leveraging on the expertise of different stakeholders and the engagement of local citizens. Municipalities and local governments are key players in the transition, as they can support the stakeholders in overcoming the barriers concerning the lack of regulations, and in guiding the transition toward "circular cities" in a synergistic and structured manner. The university that represents a relevant and historical feature of the city of Pavia may provide education on the topic, also consolidating the interaction with the stakeholders working in the territory, and favoring the students' training. This will implement and expand knowledge on the concept of sustainability and on the most available and effective tools to be adopted to create circular cities against the old model of waste cities. Our findings call for an enhancement of the commitment of public actors as active promoters of the transition toward "circular cities".

5.1 Limitations and future avenues for research

The paper presents some limitations. First and foremost, the research is based on a single case study, meaning that it allows for analytical generalization but not for statistical generalization. Further research may compare the results stemming from this study conducted in Pavia with other studies conducted in other cities (for instance, those belonging to the EC2U consortium), and may focus on the role of public actors as orchestrators of circular urban projects. We also suggest that it would be worth performing longitudinal studies to investigate over time the process of transformation from a "city of waste" toward a "circular city". Finally, we suggest deeply investigating the social aspects linked to the implementation of circular cities.

5.2 Policy implications

The illustrated case study has highlighted several crucial factors, limitations, and methodologies that can provide valuable guidance for local, national, and European policymakers. The CE approach offers solutions to address sustainability and achieve the 2030 Sustainable Development Goals (SDGs) to which both UN Member States and every EU Member State, including Italy, have committed. As demonstrated in our case study, the interconnectedness of all the goals and targets necessitates a multi-stakeholder approach to finding more suitable solutions and creating effective positive impacts at various levels.

For instance, implementing a CE approach in urban food policies would yield economic, societal, and environmental benefits, as evidenced by extant studies (Ellen MacArthur Foundation 2019; Lizzi et al. 2022). Practices aimed at preventing and reducing food waste can enhance urban regeneration, curb greenhouse gas emissions, and mitigate soil degradation, offering significant environmental benefits that also promote health. Simultaneously, these efforts can benefit those in need, improve food security, alleviate poverty, and bolster local resilience.

Our study suggests overcoming policy constraints that limit the actions of numerous local actors, both public and private, which are influenced by (i) the absence of uniform rules and common definitions or (ii) a convoluted legal framework where different standards and normative approaches are imposed by national, EU, and international rules. The collected empirical evidence suggests that there are several CE practices that could be implemented at the urban level to favor the transition from cities of waste toward circular cities. Policies should favor the implementation of these practices, by concurrently following ongoing revisions of EU acts related to Corporate Social Responsibility (CSR), sustainability, waste management (including textiles and food), and packaging, which will soon introduce new rules at the national and local levels

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Regional demolition waste treatment capacity: a case study based on the identification of building selective deconstruction value chain's stakeholders

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Abstract

The construction and demolition sector is a major contributor to waste generation, prompting European and national public authorities to adopt a waste management strategy based on circular economy (CE) principles. This strategy aims to promote the reuse and recycling of construction materials. A key prerequisite for this strategy is selective deconstruction, which allows for more efficient waste recovery by separating materials based on their treatment, reuse, recycling and landfill potential. Selective deconstruction involves a value chain that includes a range of stakeholders. This paper proposes a methodology for identifying the stakeholders involved in this value chain, from project owners to waste reclamation and recycling companies. This methodology is applied to the Lille European Metropolis (France – LEM) to estimate the Deconstruction Resources Treatment Capacity of this Region (DRTCR). Finally, this capacity is analysed in relation to the volume of resources generated by deconstruction, and to the objectives set by the circular economy strategy. Results demonstrate the importance of developing selective deconstruction at a local scale, and highlight the need for investment in this sector and potential of sustainable business.

Keywords: circular economy; construction and demolition waste; selective deconstruction; stakeholders; resources management; regional capacity.

1. Introduction

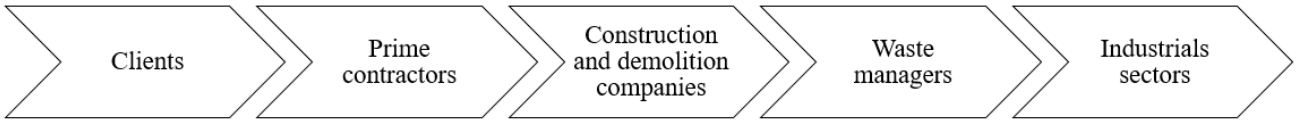
The transition from a linear to a circular economic model aims to optimize resource use to preserve natural capital (Ellen MacArthur Foundation, 2015). Throughout the 20th century, the increasing mechanization of the demolition industry and declining profitability of building materials' reusing operations led to significant growth in construction and demolition waste (C&DW) production (Ghyoot et al., 2018). In 2018, the construction and demolition (C&D) sector accounted for 35.9% (2.337 million tonnes) of the waste generated in the EU, making it the primary source of waste production (Eurostat). In France, 47.3 million tonnes of C&DW were produced in that year. In response to this problem, the concept of a circular economy (CE)

emerged in the academic literature in the early 2000s, becoming a key category of public policy in countries such as Germany[1], Japan[2], China[3] or the Netherlands[4]. The European Waste Framework Directive 2008/98/EC sets a target of 70% for non-hazardous C&D waste reuse, recycling, and material recovery by 2020 (European Parliament, 2008). In line with this goal, the French Parliament passed a "No-Waste for a Circular Economy" law in 2020 (Parliament, 2020).

In the C&D sector, selective deconstruction is a way to implement CE principles by replacing building demolition with a process that separates materials according to different treatment, reuse, and recycling sectors (Roussat et al., 2009; Assefa and Ambler, 2017; Ghyoot et al., 2018). Although private companies and public authorities increasingly use selective deconstruction, little academic literature specifically addresses this issue. Some research focuses on new deconstruction methods and programming (Sanchez et al., 2019, 2020). However, the development of selective deconstruction involves a value chain consisting of actors not only directly involved in the building site but also upstream and downstream (Tirado et al., 2021). The full commitment of owners, prime contractors, and project management assistance specialized in CE issues is required during the earliest phase of deconstruction to coordinate the various stages and actors of the worksite. Moreover, once materials are deconstructed, their treatment, reuse, or recycling may involve a range of different sectors. Therefore, the development of selective deconstruction potentially concerns many different stakeholders and jobs (Gálvez-Martos et al., 2018).

This study focuses on estimating the stakeholders and employment potential involved in an advanced selective deconstruction value chain, specifically in the Lille European Metropolis (LEM)[5] and its 95 municipalities. Through building an exhaustive database of potential stakeholders, from clients and contractors to waste reclamation and recycling companies (figure 1), this article aims to provide an overview of the CE development potential. This database is utilized to estimate the capacity of actors located in this area to treat resources generated by selective deconstruction. More specifically, the Deconstruction Resources Treatment Capacity of a Region or area (DRTCR) refers to two parameters of the construction and demolition waste management (C&DW-M): (1) the volume of products, equipment, materials, and waste resulting from selective deconstruction and generated per year from one region. For CE concept, having been removed selectively, those materials correspond with potential resources that can be recycled, recovered or re-used into building construction or rehabilitation. Then (2) the ability of workers employed by companies in the value chain and established in the area to process these resources define this capacity. The goal is to determine the ability of one Region/area to generate C&DW and its capacity to close loops in the building industry. The focus is placed on the labour force that directly handles these resources, by working on building sites, removing construction elements, transporting them to a treatment center, sorting them and preparing them for theirs recycling, recovery or re-use. Therefore, the DRTCR highly relies on the size of the workforce of the value chain, which is precisely the focus of the proposed methodology. The interest could be to help decision makers in regional communities to orientate and facilitate the implementation of public and/or private infrastructures optimizing the DRTCR of the C&DW-M.

Figure 1. Actors in the selective deconstruction value chain



Source: Author's elaboration, adapted from (Lofti, 2016)

The article first describes the multiscale regulatory framework that makes CE the main waste management strategy in the C&D sector, at the European, French and sub-national levels. The study then moves to literature review section, followed by a section describing the methodology used to create the database and estimate the DRTCR. The last section is dedicated to the main results and their discussion. Firstly, it determines the DRTCR of the LEM, and compares it with the estimated volume of

[1] Waste management law in a "closed-cycle substances" ("Kreislaufwirtschaftsgesetz") adopted in 1994.
[2] "Basic Act for Establishing a Sound Material-Cycle Society" adopted in 2000.
[3] Framework law to promote circular economy adopted in 2008.
[4] National waste management plan 2009–2021 entitled "towards a material chain policy".
[5] This article and the results it presents are the fruit of a research project carried out within an industrial chair called « RECONVERT » and financed by Lille European Metropolis and I-Site. Url : https://reconvert.wp.imt.fr/

waste generated in this area. Then, it examines the objectives fixed by public authorities in their CE strategies, showing that their achievement requires an increased DRTCR that could address gaps in the selective deconstruction value chain.

2. Contextualisation : an evolving regulatory framework

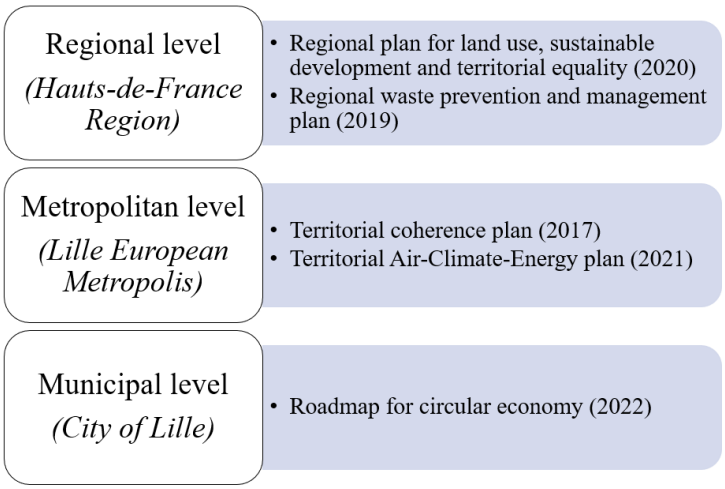
The legislative and regulatory framework at European, national, and sub-national levels demonstrates a clear and increasingly ambitious path towards the implementation of a CE in the C&D sector. Beginning in 2008, the European Union established a directive with the aim of achieving a 70% re-use, recycling, and material recovery rate for non-hazardous C&D waste. According to a 2020 report of the European Environment Information and Observation Network, most of European countries have already reach this 70% target, but "despite [these] high recycling rates, the recycling of C&DW is largely downcycling" (EIONET, 2020, p. 12). Moreover, this global rate masks substantial variations in material flows. While inert waste represents the largest volume and is relatively easy to recover, there is now a need for a more detailed waste management strategy, by adopting more precise objectives for each material. In 2015, the European Commission adopted a Circular Economy Package aimed at pushing forward the transition towards a circular economy. This package notably promotes the recycling of waste materials and sets targets for reducing landfilling. The European Commission reaffirmed its commitment to the CE strategy five years later, as part of the European Green Deal. This broader plan sets more ambitious objectives, and notably aims to achieve a climate-neutral Europe by 2050.

Similarly, France government established the *Grenelle* Law 2 in 2010, which outlined a waste planning strategy that ultimately led to the implementation of waste diagnostics for building demolition in the 2014-2020 national waste prevention program. In 2015, the "NOTRe" law (territorial organization reform) transferred waste planning jurisdiction to the regions, while the Law for Energy Transition and Green Growth established the circular economy concept as a guiding principle for the first time. By 2018, the French government had made CE a cornerstone of its waste management strategy through the Circular Economy Roadmap, which aimed to increase sorting, re-use, and recovery of demolition waste. Two years later, the "No-Waste for a Circular Economy" law further solidified this commitment by introducing an Extended Producer Responsibility (EPR) for construction material manufacturers and setting specific objectives for recovery rates for various materials. The EPR establishes an eco-contribution on the sales of construction products and materials, which is collected by sellers and transferred to Producer Responsibility Organizations (PROs). The PROs are responsible for organizing the collection, treatment, and recovery of building waste and material. The "No-Waste for a Circular Economy" law aims for a recovery rate of 88% for mineral waste and 57% for non-mineral waste by 2027. Precise objectives related to particular materials flows are also set, and their implications in terms of volume will be explored at the LEM level in section 5.

At the sub-national level in France, which refers to governance and decision-making below the national level, public actors have taken significant steps towards promoting circular economy practices. Since 2015, regions, which are the administrative level beneath the State, have taken over jurisdiction of waste planning, which is carried out through regional waste prevention and management plans. These plans outline strategies to prevent waste generation and promote circular economy practices, and are specific to each region in France. For example, the Hauts-de-France Region, which includes the LEM area, established a waste prevention and management plan in 2019, outlining its key objectives and an action plan for circular economy, with a particular focus on C&D materials. Regions also have to draw up a regional plan for land use, sustainable developmtent and territorial equality. That of Hauts-de-France, adopted in 2020, gives a prominent place to the implementation of CE in the C&D sectors, with specific objectives such as landfilling reduction, development of on-site sorting, and expansion of a territorial grid of recovery sites. Although these objectives address specific issues, their lack of precision and quantification makes it difficult to evaluate progress towards a more sustainable C&DW-M. Instead of setting specific targets, these planning documents outline the general ambitions of local authorities regarding urban planning, transportation, waste management, and energy. As shown in Figure 2, this kind of strategic documents is also implemented at the metropolitan and municipal levels. In particular, LEM adopted a territorial coherence plan in 2017, and a territorial Air-Climate-Energy plan four years later, with each setting CE objectives such as encouraging C&D waste re-use and recovery, promoting the develoment of recycling channels, or land using for waste recovery. Finally, in this multiscale regulatory framework, municipalities have also make CE a key strategy for resources management in the C&D sector. Lille for instance, the main city of the LEM, has notably adopted a roadmap for circular economy in 2022, with the ambition of creating a local platform for exchange and treatment of construction materials.

A these different scales, public authorities draw a clear path towards the implementation of CE in the C&D sector, establishing more and more precise and ambitious objectives related to resources recovery.

Figure 2. Local authorities' planning documents promoting CE in the C&D sector



Source: Author's elaboration[6]

3. Literature review

While the concept of selective deconstruction itself still requires further exploration, there has been extensive research dedicated to the application of circular economy principles in the C&D sector. These studies can be broadly classified into two categories. The first focuses on the technical and organizational challenges associated with managing C&DW. The second group of studies takes the C&D sector as a case study to inform research on circular economy more broadly. In this context, employment is among the social aspects impacted by the adoption of circular economy practices.

3.1 The construction and demolition waste management

An important part of the literature dealing with CE in the C&D sector comprises engineering science works that focus on technical and organizational processes related to C&DW-M. These works study the recovery of specific types of materials, such as concrete, metal, timber, plaster, plastic, and glass (Gorgolewski et al., 2008; Jung et al., 2015; Wijayasundara et al., 2016; Campbell, 2018; Mazzarano, 2021), or look at a particular type of building (Minunno et al., 2018). These studies suggest strategies for CE development in the sector, such as on-site recycling, manufacturing recycled aggregate, use of mass timber, but point out the fact that those strategies require improvements in organizational structures, technical knowledge, and investment in infrastructures. One of the main method used in the field is the life cycle analysis (Coelho and De Brito, 2012; Bovea and Powell, 2016; Wang et al., 2018; Brambilla et al., 2019; L. Eberhardt et al., 2019), which allows authors to highlight the environmental impact of waste demolition, and to investigate potential benefits of CE practices, which could concern the waste management as well as the building process and the type of components used in the construction. Moreover, the effectiveness of C&DW-M at the country or region scale were evaluated in the aims of improving it (Yeheyis et al., 2013; Lockrey et al., 2016; Nasir et al., 2017; Yuan, 2017; Zheng et al., 2017; Huang et al., 2018; Christmann, 2018). Those works aim at pushing policy-makers towards improvement in C&D waste management, by proposing CE strategies and objectives such as increasing recycling rate and reducing lanfill rate, adopting targeted economic incentives, or encouraging innovative

[6] All the documents mentionned are available online, on the websites of the Hauts-de-France Region: https://www.hautsdefrance.fr/ ; the LEM: https://www.lillemetropole.fr/ ; and the city of Lille: https://www.lille.fr/

technologies and market models. Other works examine waste treatment capacities in terms of the types of facilities (Mihai, 2019) or technologies used (Di Maria et al., 2018). Those studies are completed by the approach taken here, that aims to cover this issue of treatment capacities, in regard to the stakeholders of an region or area and their available labour force, as stated above in the definition of DRTCR. Indeed, although those works are of great interest for estimating generation and flows of C&D waste, especially through material flow analysis, and for exploring ways to reduce them, few of them aim to investigate stakeholders that are likely to take charge of these waste. That is why the next subsection deals with approaches in terms of CE social aspects that are, in this regard, complementary.

3.2 Circular economy in the construction and demolition sector and its social aspects

The methods for measuring and quantifying the circular economy have stimulated significant reflection and research. As results, the identification of a set of indicators that could reflect the circularity of a sector or a region has been extensively studied and discussed (Iacovidou et al., 2017; Nuñez-Cacho et al., 2018; Scarpellini et al., 2019; Fusco Girard and Nocca, 2019). Employment is often included as one of these indicators and considered in the social aspects of CE (International Labour Organization, 2011; Moreau et al., 2017, 2017; Laurenti et al., 2018; Jabbour et al., 2019; Padilla-Rivera et al., 2020; Scarpellini, 2021). These studies highlight the socioeconomic embeddedness of the CE and investigate its implementation's impacts, which extend beyond environmental considerations and affect the organization of work and employment within society. Furthermore, substantial research has focused on the CE's job creation potential (Horbach et al., 2015; Mitchell and Morgan, 2015; EHORE, 2017; Aranda-Usón et al., 2018), as well as employment structure and distribution (Repp et al., 2021), while some studies specifically address skills development (Consoli et al., 2016; Burger et al., 2019). This article follows the approach of Llorente-González and Vence (2020), who studied the repair, reuse, and recycling sectors using the second revision of the statistical classification of economic activities in the European Union (NACE Rev. 2). The authors' goal was to investigate the labour intensity of those activities defined as circular, on a European scale and using Eurostat statistical aggregates. The present article shares a similar objective, at a smaller scale corresponding with a metropolitan area, which allows for a comprehensive identification of stakeholders in a specific value chain: that of building selective deconstruction.

The academic interest in CE applied to the C&D sector is increasing, as evidenced by the growing number of systematic literature reviews (Ghisellini et al., 2018a, 2018b; Hossain et al., 2020; Ruiz et al., 2020; Superti et al., 2021). These studies aim to identity factors that could influence the adoption of CE in the sector, and their results suggest that a comprehensive framework and methodology for CE integration and evaluation are yet to be developed. To progress down this path, many studies focus on CE practices implemented by C&D companies (Chau et al., 2017; Leising et al., 2018; Chang and Hsieh, 2019; Rehman et al., 2020; Guerra et al., 2021; Guerra and Leite, 2021; Doussoulin and Bittencourt, 2022), and some provide analysis in terms of "best practices" (Jiménez-Rivero and García-Navarro, 2017; Gálvez-Martos et al., 2018). Other works explore the potential development of CE in the sector (Schultmann and Sunke, 2007; Sassi, 2008; L. C. M. Eberhardt et al., 2019; Romnée et al., 2019), and the indicators that could reflect this development (Nuñez-Cacho et al., 2018). On the scale of a company, those indicators refer in particular to waste generation, energy management, emissions and other negative externalities, materials management or the 3R principles – reduce, recycle, and reuse. However, only a few studies examine the social aspects of the sector's transformations due to CE implementation (Wuyts et al., 2019; Tomić and Schneider, 2020), or its consequences in terms of work practices (Ann et al., 2013). This latter study, with the case of Hong Kong, showed that a charge on C&DW disposal to landfills may not be sufficient to encourage actors of the C&D sector to change their building practices so as to reduce waste. This litarature suggests that CE implementation in the building sector relies not only on changes in the regulatory framework, but also on stakeholders' capacity to adapt their practices and organization to these challenges.

As no specific academic works identify stakeholders of the selective deconstruction value chain exhaustively, the following method is here proposed.

4. Methodology

4.1 Database construction

The method developed is applied to the specific area of LEM, in order to demonstrate its usefulness through a concrete case study. The metropolis covers an area of 671 km² and includes 95 municipalities, with a total population of approximately 1.1 million inhabitants. The metropolitan scale is particularly relevant to the issue of C&D waste management as it provides a consistent framework for optimizing material and waste streams, while also considering the environmental impact of transport.

In order to create an inventory of all the companies that could potentially be involved in the deconstruction value chain and are located in LEM, the database of the French National Identification System and Directory of Enterprises and their Establishments (*SIRENE*)[7] was used. This database is administered by the French national statistical institute (*INSEE*)[8], that provides data on a wide range of economic and social indicators. It contains information on every registered establishment in France and identifies each of them with a code that is related to their main activity. The codes used in this database are based on the French statistical classification of economic activities (*NAF*)[9], which operates on a similar principle as the European NACE Rev. 2. This approach builds on previous research, particularly in the field of industrial ecology (Kasmi, 2018) and repair, reuse, and recycling activities (Llorente-González and Vence, 2020).

The activities were categorized based on the four main steps of the deconstruction value chain, namely, clients and general contractors, C&D companies, waste collection and treatment companies, and outlet industries. Economic activity codes were selected through several methods. First, all codes that directly refer to the deconstruction value chain were selected. To ensure comprehensive coverage of the waste collection and treatment part, all C&DW collection points were identified using the tool provided by the French Construction Federation[10] and added any missing codes. Additionally, professional literature, particularly the Démoclès project[11], was consulted to match each type of waste with its potential forms of reusing and recycling.

However, the potential missing part of the value chain is the non-profit organizations and social businesses sector. They may intervene in the deconstruction phase through job integration workshops, and in the recovery phase via resale and recycled goods shops[12]. Although these activities are an integral part of the value chain, the associations carrying them out are generally registered under a code that refers specifically to their social aim, rather than an economic sector. To integrate them into the analysis, a census of these actors located in LEM was conducted, using professional organizations' directories[13]. As a result, 10 establishments operating in the building sector were added to the value chain.

The database was subsequently refined by removing closed establishments and liquidated companies, and classifying each actor based on the type of materials they potentially handle. Table 1 presents a comprehensive list of economic activities included in the database, along with the number of actors operating in the metropolitan area. Although they are accountable for it, clients (real estate managers) and prime contractors are not directly involved in resources treatment, in the sense that their workforce do not directly handles them. In total, the database includes 802 actors across 35 activities.

[7] "*Système national d'Identification et du Répertoire des ENtreprises et de leurs Etablissements*". Available online: https://www.sirene.fr/

[8] "*Institut national de la statistique et des études économiques*". URL: https://www.insee.fr/

[9] "*Nomenclature d'Activités Française*". Available online on the website of the *INSEE*.

[10] Source: www.dechets-chantier.ffbatiment.fr

[11] Source: www.democles.org/

[12] In France those actors are known as "*ateliers chantiers d'insertion*" (ACI), "*ressourceries*" and "*recycleries*".

[13] Those directories are available online : https://ressourceries.info/?FfF ; http://www.lesentreprisesdinsertion.org/france/annuaire-entreprises

Table 1. Overview of metropolitan actors potentially involved in the deconstruction value chain

Actors in the value chain	Economic activities	Number of establishments located in LEM
Construction and demolition companies	43.11Z – Demolition	12
	43.12A – Levelling and grading of construction sites	58
	43.12B – Site preparation	11
	43.99C – General masonry and structural work	329
	43.99D – Other specialised construction activities	38
Waste collection and treatment companies	38.11Z – Collection of non-hazardous waste	15
	38.12Z – Collection of hazardous waste	3
	38.21Z – Treatment and disposal of non-hazardous waste	8
	38.22Z – Treatment and disposal of hazardous waste	2
	38.31Z – Dismantling of wrecks	4
	38.32Z – Recovery of sorted materials	27
	39.00Z – Remediation activities and other waste management services	14
	08.12Z – Operation of gravel and sand pits; mining of clays and kaolin	5
	46.72Z – Wholesale of metals and metal ores	25
	46.73A – Wholesale of wood and construction materials	149
	46.77Z – Wholesale of waste and scrap	2
Outlet industries	13.93Z – Manufacture of carpets and rugs	6
	20.16Z – Manufacture of plastics in primary forms	2
	20.30Z – Manufacture of paints, varnishes and similar coatings, printing ink and mastics	6
	22.21Z – Manufacture of plastic plates, sheets, tubes and profiles	
	22.22Z – Manufacture of plastic packing goods	5
	22.23Z – Manufacture of builders' ware of plastic	5
	22.29A – Manufacture of plastic technical components	9
	22.29B – Manufacture of plastic consumer goods	11
	23.51Z – Manufacture of cement	8
	23.99Z – Manufacture of other non-metallic mineral products	1
	24.42Z – Aluminium production	3
	24.45Z – Other non-ferrous metal production	1
	42.11Z – Construction of roads and motorways	1
	42.99Z – Construction of other civil engineering projects	21
		11
Social and solidarity economy	82.99Z – Other business support service activities n.e.c.	1
	85.59A – Adult continuing education	2
	88.10C – Work-based social support	1
	88.99A – Other social work activities without accommodation n.e.c.	1
	88.99B – Social work activities without accommodation	5

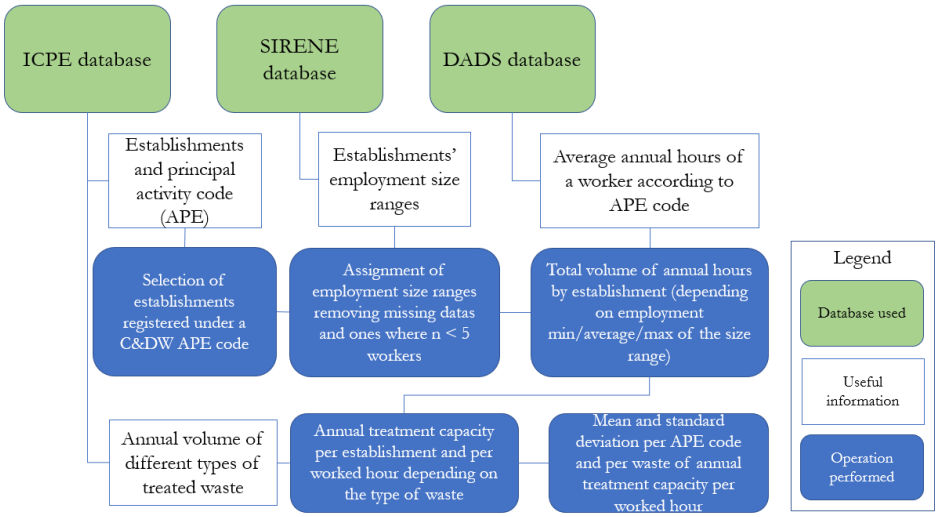
Source: Author's elaboration, codes refer to the Nomenclature d'Activités Française (NAF) and were translated using the Statistical classification of economic activities in the European Community headings (NACE).

4.2 Treatment capacities estimate

The goal is to estimate the demolition waste treatment capacity of the stakeholders in the value chain, specifically focusing on C&D companies, waste collection and treatment companies, who are primarily responsible for managing waste generated by demolitions. The estimate of their waste treatment capacity is based on the database of the Classified Installations for

Environmental Protection (*ICPE*)[14]. It is the French regulatory system for industrial facilities that have a potential impact on the environment and public health, and it contains information on every waste treatment facility in France. Data concerning the principal activity code of each establishment, the types of waste treated, and the annual volumes treated for each type were extracted. As summarized in Figure 3, using this information, an average treatment capacity per activity code per type of waste was determined, for the selected activity codes and materials that are part of demolition waste. To express the average capacities in tons per worked hour, the annual declaration of social data (*DADS*)[15] was utilized to obtain the average annual hours worked per worker per activity code. This database, which is not open-source, is established by the French national statistical institute (*INSEE*), and contains annual declarations of social data related to the employment of workers, such as wages, hours worked, social security contributions, and taxes, that French employers are required to submit to the public authorities. In addition to the information concerning the average annual worked hours, data about the distribution between workers, intermediate professions and managerial staff were also used. Indeed, as the DRTCR was defined in the introduction, it depends on the labour force that directly and concretely handles resources, and it therefore concerns annual hours worked by workers.

Figure 3. Methodology for treatment capacities estimate per activity code and per material



Source: Author's elaboration

Using the average capacities per worked hour, the capacity of each establishment located in the LEM area was estimated by referencing the employment size ranges. However, because not all workers treat every type of waste, a materials mass distribution of demolition waste was first applied to these capacities: two types of distributions were used (Appendix 1), one that concerns ratios of C&DW estimated for the French EPR implementation[16] ("EPR distribution"), the other corresponds with the study of legal declarations in France for demolition sites larger than 1000 square meters[17] ("OPTIGEDE distribution"). Both were obtained from works conducted by the French Environment and Energy Management Agency (*ADEME*)[18], a public organization that operates under the supervision of the Ministry for the Ecological Transition and Solidarity, and aims to

[14] "*Installations Classées pour la Protection de l'Environnement*". Available online: https://www.georisques.gouv.fr/

[15] "*Déclarations Annuelles de Données Sociales*".

[16] ADEME, TERRA, TBC Innovactions, ELCIMAI Environnement, Au-Dev-Ant, E. PAROLA. 2021. Etude de préfiguration de la filière REP Produits et Matériaux de Construction du secteur du Bâtiment. 29 pages. Available online : https://librairie.ademe.fr/dechets-economie-circulaire/4573-etude-de-prefiguration-de-la-filiere-rep-produits-et-materiaux-de-construction-du-secteur-du-batiment.html

[17] ADEME, OPTIGEDE, Estimation de la production de déchets de bâtiment. 5 pages. Available online : https://optigede.ademe.fr/outils-pour-les-entreprises.

[18] "*Agence de l'Environnement et de la Maîtrise de l'Energie*". URL: https://www.ademe.fr/

promote the transition towards a sustainable and low-carbon society. These distributions allow to estimate the annual treatment capacity of each establishment for each type of waste.

Some of the construction and waste collection and treatment activities involve actors that not only treat C&DW, but also public works waste (roads). The building sector generates 19% of the waste generated by building and public works, according to the French Ministry of Ecological Transition[19]. To account for this volume of waste, 81% of the total volume treated were deducted for activities related to public works waste. Figure 4 provides an overview of the different steps took to estimate the total treatment capacity of demolition waste by actors of the LEM.

Figure 4. Overall methodology for total treatment capacity estimate

Source: Author's elaboration

5. Results

This methodology allows to examine the data pertaining to the selective deconstruction value chain in LEM. Table 2 presents an overview of the value chain's scope in terms of the number of establishments, employment figures, annual worked hours, and total net payroll, which surpasses 218 million euros. Total gross payroll was calculated using the conversion ratio provided by the French Ministry of Labour, Full Employment and Inclusion[20].

Table 2. General data on the selective deconstruction value chain in Lille European Metropolis

Actors in the value chain	Number of establishments (LEM)	Number of employees (mean of employment size ranges)	Total annual worked hours	Total net payroll (€)	Total gross payroll (€)
Construction and demolition companies	448	2 485	3 278 215	47 312 909	80 431 945
Waste collection and treatment companies	254	4 162	6 124 887	87 274 754	148 367 081
Outlet industries	90	2 990	4 335 500	73 311 810	124 630 077
Social and solidarity economy	10	489	709 050	10 101 793	17 173 048
Total	**802**	**10 126**	**14 447 651**	**218 001 266**	**370 602 152**

Source: Author's elaboration, based on data of SIRENE and DADS databases established by the French Institut National de la Statistique et des Etudes Economiques (INSEE)

As a basis of comparison, Eurostat data are referred to, and more specifically the wages and salaries by NACE Rev. 2 activity data. It provides data concerning the mean wages and salaries annually earned by a full-time employee, per activity. As shown

[19] Source: https://www.ecologie.gouv.fr/dechets-du-batiment
[20] This ratio is 1.7. Source: https://code.travail.gouv.fr/

in Table 3, NACE Rev. 2 activities corresponding with the four groups of actors in the value chain were selected. The number of employees working in LEM establishments (Table 2) was then used to calculate the total gross payroll, which is in total very similar with the one calculated with *INSEE* data, with only 1.5% of variation. This similarity demonstrates the reproducibility of this method, and this finding suggests that it can be applied to other European regions as well.

Table 3. Comparison between total payrolls calculated with Eurostat and INSEE data

Actors in the value chain	NACE Rev. 2 activities	Corresponding NAF activities	Mean wages and salaries, per employee in full-time equivalents, per year	Total gross payroll in € (Eurostat)	Total gross payroll in € (*INSEE*)
Construction and demolition companies	[F41] Construction of buildings [F43] Specialised construction activities	43.11Z 43.99C 43.12A 43.99D 43.12B	38 323	95 233 897	80 431 945
Waste collection and treatment companies	[E38] Waste collection, treatment and disposal activities; materials recovery	38.11Z 39.00Z 38.12Z 08.12Z 38.21Z 46.72Z 38.22Z 46.73A 38.31Z 46.77Z 38.32Z	34 688	144 371 456	148 367 081
Outlet industries	[C] Manufacturing	13.93Z 22.29B 20.16Z 23.51Z 20.30Z 23.99Z 22.21Z 24.42Z 22.22Z 24.45Z 22.23Z 42.11Z 22.29A 42.99Z	41 727	124 763 730	124 630 077
Social and solidarity economy	[Q88] Social work activities without accommodation	82.99Z 88.99A 85.59A 88.99B 88.10C	24 129	11 799 081	17 173 048
Total				**376 168 164**	**370 602 152**

Source: Eurostat, Labour cost, wages and salaries (including apprentices) by NACE Rev. 2 activity, online data code: LC_NCOSTOT_R2

The methodology described in the previous section allows to estimate the DRTCR of the LEM's value chain. It must be taken into consideration that the same resources can be handled by different stakeholders. three groups have been defined and correspond to the main stages of C&DW-M: after having been removed from a building by workers of a first company, workers of a second one can transport them to a treatment center ran by a third one. To avoid counting operations concerning the same resources multiple times, value chain's stakeholders are divided into three different groups. As shown in Table 4, Group A consists of stakeholders whose labour force works directly on building sites, Group B includes stakeholders involved in resource collection and treatment, and Group C comprises stakeholders engaged in resource reselling (46.72Z, 46.73A, 46.77Z), mineral waste recovery (08.12Z), and public works and construction activities that are not primarily focused on waste management and treatment but may involve it as part of the construction process (43.12A, 43.12B, 43.99C, 43.99D). These stakeholders (group C) are integrated in the selective deconstruction value chain because, even if they generally use new or "virgin" products, equipment and materials, they might be able to reintroduce resources generated, collected and treated by the two other groups, in a complete circular economy which closes a large number of loops into the building industry. Thus, they are here considered as "stakeholders closing loops for building industry".

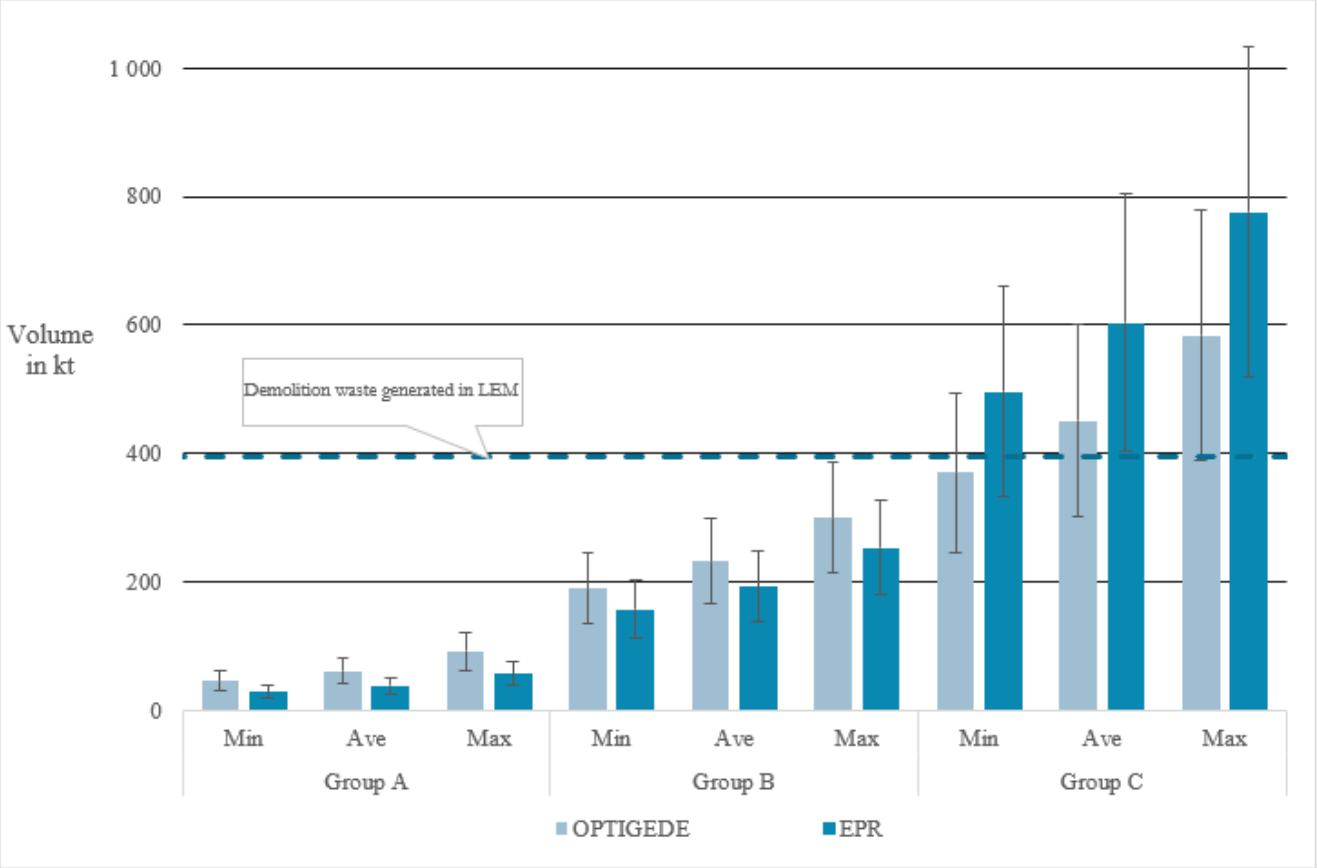
Table 4. Stakeholders' distribution according to the order of resources' handling

Group A Resources generation from selective deconstruction	Group B Resources collection and treatment	Group C Stakeholders closing loops for building industry
43.11Z – Demolition 38.12Z – Collection of hazardous waste 38.31Z – Dismantling of wrecks 39.00Z – Remediation activities and other waste management services	38.11Z – Collection of non-hazardous waste 38.21Z – Treatment and disposal of non-hazardous waste 38.22Z – Treatment and disposal of hazardous waste 38.32Z – Recovery of sorted materials	43.12A – Levelling and grading of construction sites 43.12B – Site preparation 43.99C – General masonry and structural work 43.99D – Other specialised construction activities 08.12Z – Operation of gravel and sand pits; mining of clays and kaolin 46.72Z – Wholesale of metals and metal ores 46.73A – Wholesale of wood and construction materials 46.77Z – Wholesale of waste and scrap

Source: Author's elaboration

The results are presented in Figure 5, according to the two types of mass distribution that were used: the "EPR distribution" that concerns all waste of the building sector, and the "OPTIGEDE distribution" that is specific to demolition waste. While estimating average capacities per worked hour, based on the employment size ranges of ICPE establishments, the minimum, the average and the maximum of the size ranges were used, leading to a maximum, an average, and a minimum capacity. Those capacities were then applied to the employment size ranges of the actors established in LEM. The minimum, the average and the maximum of the size ranges were used. The results present the mean and the standard deviation of the metropolitan actors, for the minimum (Min), the average (Ave) and the maximum (Max) capacities.

Figure 5. Annual DRTCR of LEM's actors



Source: Author's elaboration

Although the results obtained using the two mass distributions are similar in magnitude, there are still noticeable differences, especially for group C. On average, the estimated DRTCR for this group ranges from 450kt when using OPTIGEDE to 600kt when using EPR. The reason for this is the difference in the methodology underlying those distributions. The OPTIGEDE distribution relies on legal declarations of waste and materials generated specifically by demolition sites. On the other hand, the EPR distribution considers both C&DW, and is based on macro-estimates at the national level. Group C comprises stakeholders whose activities are not directly related to demolition waste management, but rather to public works and construction. Therefore, it is not surprising that their capacity, as estimated from OPTIGEDE, is significantly lower than the one estimated from EPR.

6. Discussion

To contextualise the results, the volume of demolition waste generated in the LEM area can be estimated using national data on a per capita basis, since there are no official data at the metropolitan level. The waste produced by the construction industry is divided into two main sectors: the building sector and public works. In France, according to the French Ministry of Ecological Transition[21], public works represents 80% of the total waste volume, which amounts to 224 million tons. Within the building sector, waste generation is divided between demolition (49%), building renovation (38%), and new construction (13%).

[21] Source: https://www.ecologie.gouv.fr/dechets-du-batiment

However, it's important to note that these values may not include preliminary demolition, which is often part of construction sites. In France, construction sites can be declared without including this preliminary deconstruction. Therefore, a detailed analysis of each site can provide a more accurate view of waste distribution in the sector. Nevertheless, those figures allow to estimate the volume of demolition waste generated in LEM. The French building sector produces a yearly total of 46 million tons of waste, out of which 49% is generated by demolition, amounting to 22.5 million tons. The population of LEM was 1.17 million according to the 2018 census, which represents 1.75% of the total French population of 67.16 million in the same year. Applying this percentage to the national volume of demolition waste yields an estimate of 394,105 tons of waste at the metropolitan level, as shown in Figure 5.

The average DRTCR of the group B, which comprises stakeholders involved in resource collection and treatment, is approximately 200kt. According to the methodology proposed here, metropolitan waste collection and treatment actors (group B), even under the assumption of a maximum capacity, are unable to provide the LEM area a sufficient capacity to manage this volume of resources. This result is even clearer for group A, that comprises demolition companies, collection of hazardous waste and remediation activities. With an average DRTCR of 38kt (EPR distribution) to 61kt (OPTIGEDE distribution), the study shows that stakeholders established in LEM have not a sufficient capacity to take charge of all deconstruction works of the area. Thus, results showed that most of deconstruction sites, as well as transport and treatment of generated waste, are taken into charge by actors operating in LEM but established outside its geographical area (activities related to Group A and Group B).

Group C presents a much higher DRTCR, with an average of 450kt to 600kt depending on the distribution used. The stakeholders it comprises have the potential to reintroduce the resources processed by the two other groups in the building industry. Indeed, resources management and treatment may already be part of their activities. For example, levelling and grading of construction sites may involve the removal and disposal of soil and other resources, and masonry and structural work may involve the handling and disposal of construction debris. That is why, without any new infrastructures dedicated to C&DW-M, they might help closing the gap identified between the estimated volume of demolition waste and the DRTCR of the group B. Otherwise, the gap pointed out here suggests that a large proportion of deconstruction resources – about half of them according to the estimates of this study – is treated by actors established outside the LEM area. Based on these findings, the DRTCR could be a relevant indicator to help decision makers in regional communities supporting the implementation of new relevant activities of C&DW-M.

The results presented above apply to all materials, and it is proposed to analyse if the DRTCR remains relevant when focussing on each material individually. This is especially significant given that France's establishment of the EPR system has already set objectives for specific materials. The decree of 10 June 2022, which relates to the No-Waste for a Circular Economy law and concerns the extended producer responsibility for construction materials, states that the recycling rates for wood, plaster, plastic, and glass should be raised by 2027 to 45%, 37%, 24%, and 18%, respectively (while they are currently at 41%, 16%, 17% and 3%, respectively). Group B capacities mainly concerns treatment and recycling of these materials. To achieve these recycling objectives, the hypothesis is that these materials are selectively deconstructed, collected, and processed individually before being recycled. Since the legislation focuses on these specific materials, let’s examine the DRTCR of the LEM for these flows.

Using both EPR and OPTIGEDE distributions, the respective shares of wood, plaster, plastic and glass were imputed to the estimate built above of 394,105 tons of demolition waste generated in the LEM area. The resulting volumes are compared, in Table 5, with the DRTCR of groups B, for each considered material flow. The capacity rates presented in these tables represent this DRTCR, in comparison with the estimated volumes of materials generated in LEM.

Table 5. DRTCR for specific material flows focused by French legislation

Distribution	Material	Share in the material mass distribution[22]	Estimated volume generated in LEM (in tons)	Volumes to be recycled according to fixed objectives	Annual DRTCR (in tons)	Capacity rate (± standard deviation)
EPR	Wood	4.9%	19 311	8 690	2 586	30% ±9%
	Plaster	0.3%	1 182	437	69	16% ±4.7%
	Plastic	0.4%	1 576	378	65	17% ±5%
	Glass	0.4%	1 576	284	14	4.8% ±1.5%
OPTIGEDE	Wood	1.11%	4 375	1 969	497	25% ±7.6%
	Plaster	0.24%	946	350	5.7	1.6% ±0.5%
	Plastic	0.04%	79	19	7.7	40% ±12%
	Glass	0.02%	158	28	0.5	2% ±0.6%

Source: Author's elaboration

Since this pertains to specific materials flows, the differences between the results obtained are more noticeable, primarily due to the weight discrepancy provided based on the mass distributions. Table 5 shows that this discrepancy ranges from 1 to 10 for plastic and 1 to 20 for glass. Beyond these differences, it was found that the DRTCR of LEM's actors does not match any of the volumes to be recycled according to the objectives set by legislation. Using the EPR distribution, the capacity rate ranges from 4.8% for glass, to 30% for wood. With the OPTIGEDE distribution, this rate ranges from 1.6% for plaster, to 40% for plastic. Those results highlight significant gaps in comparison to the volumes that need to be treated, indicating the need for a substantial additional capacity. But since there are large differences in the volumes and capacity rates between EPR and OPTIGEDE distributions, those results for specific flows should be viewed with caution and shall not be considered as a truthfully representation of the actual capacity of LEM's actors.

The results obtained for these flows, as well as those for all material flows, indicate that there is still a significant gap in comparison to the volumes generated in LEM, indicating the need for a substantial additional capacity to meet the circular economy (CE) targets. This suggests once again that a large portion of the demolition waste generated in the metropolis might have to be treated outside its geographical area, which could result in increased transport emissions. In this regard, developing a selective deconstruction value chain sustainably and at a local scale seems crucial. Coordination between value chain stakeholders is essential, but it may not be enough to address the significant challenges of CE. Public actors and private stakeholders might need to invest in new waste treatment infrastructures to meet the targets set by the regulatory framework. While this investment may seem like a constraint due to the climate emergency, it presents an economic opportunity for the metropolitan area to create thousands of new jobs that are unlikely to be relocated.

7. Conclusion

The focus of this article has been on the role of selective deconstruction, a key but not yet automatic lever for implementing CE in the C&D sector. This method has the potential to significantly increase waste treatment, reuse, and recycling ratios, thanks to its ability to better divide material flows. However, to achieve this, it requires the involvement of multiple stakeholders across the selective deconstruction value chain, and not just the method itself. The first goal of this article was to provide a replicable and comprehensive methodology for identifying these stakeholders, which relies on the statistical classification of economic activities. The reproducibility of this method makes it a promising tool for future research in other French regions and, with sufficient time and resources, in other European areas as well. In fact, the comparison with Eurostat data revealed very similar results, indicating that the method can be effectively applied to other regions.

[22] The share of plaste ris the sum of "Gypsum plasterboards and planks", "Inert matrix with plaster" and "Insulation composite with plaster". The share os wood is the sum of "Untreated wood" and "Slightly adjuvanted wood".

This methodology was applied to the area of LEM, allowing to identify the stakeholders involved in the selective deconstruction value chain and to assess their capacity to treat materials and waste from deconstruction. The analysis conducted in this study showed that LEM, with approximately 10 000 employees in the sector, has a significant potential for CE development. It was found that the three groups of stakeholders comprising the selective deconstruction value chain, has an average DRTCR of around 50kt for group A (resources generation from selective deconstruction), 200kt for group B (resources collection and treatment), and 450kt to 600kt for group C (stakeholders closing loops for building industry). Taking into consideration that LEM has an estimated volume of demolition waste of 400kt, the highlights the need to develop the value chain, especially by involving stakeholders of group C. Similarly, looking at specific materials flows that have been focused by legislation, the results show that the current capacity may not be sufficient to achieve the CE strategy and its objectives.

However, the DRTCR's reliability at this level of granularity is questionable, as the results showed significant differences depending on the mass distribution used. Although the DRTCR built in this paper is a good indicator at the scale of all material flows, there is still some work to be done to make it truly relevant at a finer level of granularity, flow by flow. This work could benefit greatly from improved waste traceability, that could provide more precise and accurate data to support the DRTCR's calculations. In this regard, the implementation of the EPR for construction materials may help. Indeed, producer responsibility organizations responsible for this implementation are obligated to ensure an effective traceability of the waste they process.

The findings of this study have significant implications for the economic and environmental sustainability of LEM, and by extension, other urban areas that face similar challenges in managing C&D waste. By adopting CE strategies, LEM can reduce its dependence on virgin materials, create new jobs that cannot be outsourced, and reduce greenhouse gas emissions. Nonetheless, the development of local waste recovery economic sectors and infrastructures still requires a great deal of effort. The methodology presented in this article aimed to steer public policy towards more sustainable resource use and management, by highlighting what still need to be done. The implementation of CE and the attainment of objectives hinge indeed on the involvement of all actors in the value chain, as well as the support of public authorities.

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Appendices

Appendix 1. Detailed materials mass distributions used

Materials	EPR distribution	OPTIGEDE distribution
Bituminous mixtures	-	0.79%
Unpolluted soil	7.6%	0.19%
Concrete and stones	37.2%	70.9%
Tiles and bricks	7.6%	1.81%
Ceramic	-	0.26%
Glass without joinery	0.4%	0.02%
Mixed inert waste	22.9%	16.7%
Others inert waste	-	1.22%
Gypsum plasterboards and planks	1.3%	0.06%
Inert matrix with plaster	-	0.13%
Insulation composite with plaster	-	0.05%
Untreated wood	4.9%	0.72%
Slightly adjuvanted wood	-	0.39%
Windows and other glazed openings	-	0.01%
Metals	6.6%	2.87%
Plastics	0.5%	0.04%
Minerals wools	0.5%	0.06%
Biosourced insulation	-	0.01%
Other insulating materials	-	0.42%
Waterproofing complex not containing tar	-	0.02%
Floor coverings	-	0.04%
Non-hazardous waste electrical and electronic equipment	-	0.01%
Mixed non-hazardous waste	7.4%	1.27%
Plants	-	0.03%
Topsoil	-	0.05%
Other non-hazardous non-inert waste	0.2%	0.4%
Asbestos bound to inert materials	1.2%	0.44%
Other types of bound asbestos	-	0.05%
Friable asbestos	-	0.1%
Bituminous mixtures containing tar	-	0.05%
Waterproofing complex not containing tar	-	0.001%
Paints containing dangerous substances	-	0.001%
Wood treated with dangerous substances	0.03%	0.04%
Equipment containing dangerous refrigerant fluids	-	0.001%
Lights	-	0.003%
Other waste electrical and electronic equipment containing dangerous substances	0.4%	0.01%
Soil containing dangerous substances	-	0.57%
Other hazardous waste	1.1%	0.31%

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Understanding the concern to communicate climate change in Northeast of Catanduanes, Philippines

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Abstract

The study understands the levels of concern and communication strategies regarding climate change causes, effects, and mitigation, as influenced by the respondent's sex, age, educational attainment, and position within the Barangay in the Northeast of Catanduanes, Philippines. The barriers to effective climate change communication are also thoroughly investigated. A mixed-methods approach utilizing quantitative and qualitative methodologies through an online survey was employed. Through the survey, comprising 154 valid responses, it was observed that females and males exhibit considerable concern regarding climate change, with variations in prioritizing causes, effects, and mitigation strategies. Age-based analysis reveals differences in preferred strategies, where younger respondents emphasize renewable energy, and the older demographic favors interpersonal communication. Educational attainment positively correlates with a heightened concern for effective mitigation strategies, emphasizing the role of education in fostering informed responses to climate challenges. The study highlights distinctive concerns and strategies between Barangay Residents and Officials, underlining the need for tailored approaches considering different priorities. In identifying primary barriers, such as lack of information and financial constraints, the study recommends multifaceted solutions. These include sex-focused engagements, age-specific efforts, educational drives, customized Barangay plans, and tackling communication challenges, aiming to enhance community-centric solutions and overcome barriers associated with climate change communication within the local community. This research provides nuanced insights into the varied demographic, psychological, and social factors influencing climate change communication. The findings are aligned with established theories and prior research, emphasizing the importance of tailored strategies and diverse communication approaches to engage diverse audiences and address climate change concerns effectively.

Keywords: Barangay; Climate change communication; Catanduanes; Local community

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1. Introduction

In the contemporary era, climate change stands as one of the most critical challenges globally, recognized as an imperative focus under the United Nations Sustainable Development Goals (UN SDGs), prominently highlighted within Goal 13: Climate Action (Neal, 2016; Bhore, 2016). The urgency to address this intricate and continually evolving climate change phenomenon has grown increasingly apparent, necessitating a profound understanding of its impacts and the implementation of effective communication strategies, particularly within local communities (Canfield et al., 2021; Nash et al., 2019). The global discourse on climate change is shaped by various international agreements and frameworks (Anwar et al., 2019; Cynk, 2018; Ebi et al., 2016). Notably, the Paris Agreement, a pivotal international treaty operating under the United Nations Framework Convention on Climate Change (UNFCCC), stands as a cornerstone for international cooperation in combating climate change (Senathirajah et al., 2023; Pietrapertosa et al., 2021). This landmark agreement calls for unified efforts among nations to limit global temperature rise and adapt to its impacts. Within the Philippine context, legislative instruments such as the Climate Change Act of 2009 established the legal framework for addressing climate-related challenges, emphasizing the necessity for strategic communication, education, and community engagement to mitigate its impacts (Zaplan, 2023; Pulhin & Tapia, 2022). These legal foundations underscore the critical importance of informed communication strategies in engaging local communities to address and adapt to the multifaceted challenges posed by climate change.

Climate change is a complex and gradually unfolding phenomenon that necessitates effective communication to foster understanding and action. As posited by Spence (2011), grasping climate change often relies on observable weather patterns and seasonal events, serving as fundamental indicators for individuals to comprehend this intricate process. In the context of the Philippines, which endures an average of 20 typhoons annually (Genilo, 2018), crisis communication has become a standard procedure during calamities. Moreover, higher education institutions (HEIs), as emphasized by Cuaresma (2017), play a significant role in addressing climate change issues through instruction, research, and capacity building.

Communicating about climate change remains challenging, as highlighted by Lyytimäki et al. (2013), due to its complexity and the limited sources available for effective communication. However, achievable solutions, such as harmonizing multiple communication channels and forming partnerships, can enhance communication efforts (Lyytimäki et al., 2013). According to Moser (2010), communicators often face skepticism regarding human-induced global climate alterations. Addressing this skepticism, as supported by Hine et al. (2013), proves essential in bettering climate change communication, although it might not entirely achieve the goals of climate change programs.

The involvement of local communities in formulating climate change solutions, as demonstrated by Dulic et al. (2016), is a crucial aspect. This aligns with the current study's approach, targeting barangay officials and their residents—the primary recipients of climate change communication at the local level. Ballantyne (2016) asserts that communication transcends conveying technical information and instead serves as a practice influencing the truth about climate change as an ethical, cultural, and sociological occurrence. Moreover, Moser (2017) emphasizes the need for more guidance in communicating and combating climate threats amidst long-term environmental degradation. Floranza (2020) further underlines that awareness alone might not drive effective climate change mitigation.

In light of these scholarly perspectives, this study intends to delve into the communication dynamics surrounding climate change within the Northeast of Catanduanes, Philippines. By investigating the profile, level of concern and common strategies to communicate climate change, and the perceived barriers among barangay officials and residents, this study aims to bridge existing gaps in climate change communication strategies tailored to the community's diverse demographics. Addressing these gaps and barriers holds crucial significance in fostering informed decision-making, mobilizing communities, and driving behavioral change in the collective effort to combat climate change.

Aligned with global and national climate change agendas and considering the prevailing research gaps, this study is a vital academic pursuit. By providing insights into localized communication strategies, it informs policy formulation, educational outreach, and community engagement. The ultimate goal is to empower and mobilize communities in effectively combating the challenges posed by climate change (Leal et al., 2023).

1.2 Statement of the Problem

The study understands the concern of communicating Climate Change in the Northeast of Catanduanes, Philippines. Specifically, the study answered the following questions: 1. What is the level of concern and common strategies to communicate Climate Change among the Barangay respondents in Northeast Catanduanes in terms of A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation according to their A) Sex; B) Age; C) Educational

Attainment; and Position in the Barangay?; 2. What are the Barriers to communicating Climate Change among the Barangay respondents, and what further details explain the barriers to communicating Climate Change?

2. Literature review

This portion presents International and local papers that may clarify the variables of the present study.

Climate Change Versus Sex

The study by Zainulbhai (2015) unveiled that Women, more than men, are noticeably more worried about climate change impacting them personally, particularly in wealthier nations. In many developed countries, including the U.S., Canada, Germany, and South Korea, women tend to see climate change as a severe problem, feel concerned about its potential personal harm, and advocate for significant lifestyle changes to combat it. For instance, in the U.S., there is a significant difference: 17% more women view climate change as a serious issue compared to men. Similar trends are observed in Canada and Australia, with women expressing 12 to 13 percentage points more concern than men in their respective countries. This gender gap extends to concerns about personal harm from climate change. For example, in the U.S., 69% of women worry about being personally affected, while only 48% of men share the same concern. This trend is seen in other surveyed countries, such as Germany and Canada, where women exhibit 14 to 15 percentage points higher concerns than men.

The local present study shares similarities with the global findings that reveal a notable trend: women tend to express greater concern about the personal impacts of climate change compared to men. As observed in the broader global study across developed nations, the local research here also indicates a similar gender discrepancy in climate change concerns.

Understanding and acknowledging this discrepancy is crucial in shaping local strategies and initiatives related to climate change. Recognizing that women exhibit higher levels of concern can guide tailored approaches to engage and involve them more effectively in local climate action plans. Leveraging the specific interests and priorities of women can be instrumental in fostering more vital community awareness and mobilization for climate change initiatives at a local level.

The study of Desrochers et al. (2019) provided discussion focuses on the consistent observation that women tend to exhibit higher pro-environmental attitudes and engage more in conservation behaviors compared to men. This finding is substantiated across various studies and is considered a robust aspect of environmental psychology. The discussion highlights the importance of this gender disparity in the context of societal efforts to combat environmental degradation. It emphasizes the need to investigate the underlying reasons for these differences, specifically through the lens of personality traits, notably conscientiousness. The studies touch upon the exploration of continuous gender measures, indicating that gender differences might manifest differently from biological sex. Results suggest that while conscientiousness continues to mediate gender differences in environmental behavior, gender variance might impact protectionist attitudes differently. The study of Desrochers et al. (2019) emphasizes the importance of conscientiousness in mediating gender differences in pro-environmental attitudes and behaviors. Encouraging conscientiousness among men could potentially bridge the gap in environmental engagement between genders.

McCarthy and Citizen (2020) reported that Climate change affects everyone, but it is worsened by gender inequality. Extreme weather events like heat waves, droughts, and storms harm women more. Why? Women often face poverty, limited rights, and violence, making them more vulnerable. As climate change worsens, women will face the toughest challenges. The Paris climate agreement aims to help women deal with these hazards. The International Panel on Climate Change noted that women's workload, health risks, and mortality due to climate hazards are higher compared to men, thanks to gender inequalities. This inequality limits women's ability to take action against climate change. Lack of resources, education, information, and unequal rights affect what women can do in the face of climate change.

McCarthy and Citizen (2020) further claimed that the future might seem challenging, but women globally show incredible resilience. They lead movements for climate action, promote clean energy, and create sustainable, cooperative communities. It is important to note that women are not just victims of climate change. Their active involvement and leadership can create positive change in their countries and communities.

Consistent with Desrochers et al. (2019) and McCarthy & Citizen (2020), the present study highlights the necessity for targeted strategies. Leveraging women's slightly higher concern can effectively propel climate initiatives. This echoes the broader trends observed, emphasizing the importance of tailored approaches to engage and mobilize women, fostering community awareness and impactful climate action.

Climate Change Versus Age Group

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Funk, C. (2021) survey by the Pew Research Center delineates significant generational disparities in attitudes and engagement concerning climate change. Younger cohorts, notably Gen Z and Millennials, exhibit more pronounced involvement both online and offline in addressing climate concerns. This involvement encompasses personal actions such as donations, volunteerism, and advocacy through contacting elected officials, attending rallies, and discussing climate change within their social circles. Notably, younger generations display a higher degree of engagement with climate-related content on social media, sharing posts and interacting with accounts focused on climate issues. While a consensus exists on prioritizing alternative energy sources over fossil fuels, there is a distinct generational divide regarding more extreme measures, such as completely phasing out gasoline-powered vehicles and eliminating the use of oil, coal, and natural gas. Notably, within the political landscape, disparities persist, with younger Republicans less supportive of increased fossil fuel usage compared to older Republicans and showing greater willingness to phase out gasoline-powered vehicles. Democrats across generations largely support climate action, but younger Democrats exhibit more pronounced favor toward policies entirely breaking from fossil fuels.

Funk, C. (2021) also reveals emotional and knowledge gaps influenced by social media engagement, with deeply concerned individuals expressing more anxiety and anger in response to climate-related content. Additionally, there is a growing divergence in trust and perception of expertise in climate scientists, with Democrats increasingly trusting their understanding while Republicans become more skeptical, echoing the broader partisan divide on trust in scientists. These findings highlight the complex interplay between age, political affiliations, media engagement, and trust in shaping attitudes toward climate change and associated policy measures.

Ballew et al. (2019) reported that Younger Americans, compared to their older counterparts, are notably more concerned about global warming, as evidenced by higher levels of worry among adults aged 18 to 34 compared to those aged 55 or older. However, despite this elevated concern, there needs to be more certainty about the extent of their engagement with the issue. While younger Republicans are more inclined to acknowledge the reality and human causes of climate change, the generational gap in views on this subject is narrower among them than among older Republicans. Conversely, younger Democrats exhibit varied beliefs compared to older generations within their party. In the upcoming 2020 Presidential election, younger generations, projected to constitute a significant portion of registered voters, prioritize global warming as an important issue in their voting decisions. The potential impact of the youth vote on climate policy is considerable, highlighting the need to engage and mobilize younger individuals effectively. Initiatives such as the Green New Deal and youth-led movements have successfully captured the attention of young adults and inspired action, signaling the influence young voices can have in shaping policies concerning climate change.

Frumkin et al. (2012) discussed that Climate change poses a challenging and multifaceted issue known as a "super wicked problem" due to its complexity, uncertain outcomes, and the long-term nature of solutions. As society ages, understanding how older individuals perceive and engage with climate change becomes increasingly important. Aging populations represent a significant portion of voters and consumers, capable of influencing behavioral choices and policies. Their attitudes toward climate change vary; some may be more vulnerable to its health impacts, while others may prioritize leaving a positive legacy for future generations. Assumptions that older individuals tend to become more conservative are not always accurate; attitudes toward climate change vary and are not solely determined by age. Some studies show older individuals worrying about global warming but doubtful about its existence. This discrepancy between concern and certainty is puzzling.

Frumkin et al. (2012) further said there are varied perspectives on how older individuals maintain or change their values over time, with influences from historical events and cohort effects. Despite general trends suggesting more conservative voting patterns with age, older individuals do not consistently vote based on their interests, further complicating this dynamic. Notably, older individuals' knowledge and attitudes regarding climate change are diverse. Some studies indicate higher concern among older age groups, while others suggest skepticism or disengagement. This divergence between attitudes and actions highlights the complexity of environmental issues in survey research. Key attributes linked to aging, such as wisdom and the desire to leave a positive legacy, offer potential support in addressing climate change. Wisdom, acquired through experience, suggests that older individuals can make balanced and far-sighted judgments. Additionally, the desire to leave a legacy for future generations might encourage policies and practices that reduce greenhouse gas emissions and adapt to climate change.

Frumkin et al. (2012) ultimately said that to engage and leverage the potential of older adults in addressing climate change, several strategies could be implemented. Encouraging public discussions about intergenerational responsibilities, revising economic approaches to discounting future investments, and fostering environmental volunteerism among elders are potential avenues. Furthermore, tailored communication strategies, intergenerational dialogues, and research focusing on understanding the factors influencing older individuals' attitudes toward climate change are essential.

The local study found that different age groups hold distinct concerns about climate change, aligning with the abovementioned authors. For instance, Ballew et al. (2019) also observed higher worry among younger Americans than older individuals, echoing the local study's discovery of increased concern in younger age brackets. Similarly, both studies noted uncertainties about younger individuals' active engagement with climate change. Frumkin et al. (2012) emphasized the

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diversity of attitudes among older age groups, akin to the local study's recognition of varied concerns across different age brackets. Both studies also suggest tailored interventions as crucial, echoing the need for customized strategies to engage various age groups effectively. Funk (2021) highlighted political differences among younger age groups regarding climate change, aligning with the local study's identification of political variations within younger demographics. Both studies emphasize the importance of age-specific strategies to address climate change concerns across different generational groups.

Climate Change Versus Educational Attainment

Ambasz et al. (2023) make a comprehensive review that addresses the interrelation between human development, particularly education, and its impact on environmental behavior concerning climate change. Despite a predominance of observational studies, limited causal research suggests a correlation between higher education levels and pro-environmental attitudes. Adaptation and mitigation strategies have been proposed, emphasizing the role of education as a catalyst for fostering environmentally conscious behaviors. The conceptual framework highlights the potential pathways between education and pro-environmental behaviors, but establishing causality remains challenging. Research efforts employing various econometric methods and analyses of compulsory schooling laws hint at a positive association between increased education and climate literacy. Nonetheless, there is a notable need for extensive research to conclusively determine the impact of education on fostering environmentally responsible behaviors and garnering support for climate policies.

Zaval and Cornwell (2017) underscore the crucial role of education and behavioral science in driving pro-environmental action, especially in the context of climate change awareness and sustainability. While research in this field has primarily been conducted in the United States and Europe, global applicability still needs to be improved, necessitating a cross-cultural approach to understanding diverse contextual and cultural factors influencing climate change attitudes and behaviors. The study emphasizes non-monetary interventions, citing the powerful impact of behavioral approaches, such as default options and appeals to social norms, in influencing environmentally responsible actions. However, it notes the need for caution in their application, mainly when these approaches involve non-trivial consumer costs. The report suggests that these behavioral nudges complement, rather than substitute, other economic incentives or mandates. Integrating insights from behavioral science into public policy and developing large-scale behavioral interventions would be instrumental in promoting environmental responsibility. Furthermore, the report advocates for incorporating behavioral science into humanitarian and environmental organizational strategies, emphasizing the need for ongoing research partnerships to enhance sustainable decision-making practices and improve the effectiveness of such organizations.

Ledley et al. (2017) emphasize the crucial connection between education and addressing the pressing emissions gap stipulated by the Paris Agreement. It argues that enhancing society's comprehension of climate change, its associated risks and the necessary energy transition demands an education push that transcends scientific knowledge. This approach integrates multifaceted concepts across various disciplines, encompassing emotional, social, and cultural aspects. Employing a systems thinking framework, education emerges as a potent force to drive swift societal transformation. The figures outlined in the article illustrate the role of education in fostering climate-informed decision-making, boosting social willingness for action, and preparing a skilled workforce for transitioning to a sustainable future. While many existing climate change education initiatives have successfully elevated climate and energy literacy and community capacity, challenges persist in coordinating efforts across diverse audiences, managing resources, and scaling up effective programs. It is emphasized that education at all societal levels is pivotal in fostering knowledgeable and responsible leadership across governmental, business, and community sectors, enabling better decision-making and facilitating proactive citizen engagement.

The current local study highlights the positive correlation between higher education and heightened concern for climate change, echoing Ambasz, Gupta, and Patrinos (2023), who emphasize education's role in fostering pro-environmental attitudes. Zaval and Cornwell (2017) echo the importance of education by highlighting the impact of behavioral approaches in promoting environmentally responsible actions. Ledley, Rooney-Varga, and Niepold (2017) stress education's role in fostering informed leadership and proactive citizen engagement. All align with the local study, emphasizing the need for education-based initiatives to promote awareness and knowledge about climate change across diverse educational levels, fostering a more responsive society.

Climate Change among the barangay residents and officials

Alcantara et al. (2023) study reveals valuable insights into the awareness and risk perceptions of climate change in vulnerable coastal areas, highlighting the impact of climate-related events and socio-demographic characteristics within these communities. While a significant proportion of participants (82%) displayed high awareness of climate change, there remains an 18% segment who still need to be made aware of its existence. Primary climate change impacts observed or experienced included temperature rise and excessive rainfall, while other effects like declining income, sea level rise, and floods were observed less frequently. Of these experiences, temperature rise and excessive rainfall significantly predicted climate change awareness. Significantly, experiences or observations of sea level rise were strong predictors of risk perception regarding climate change impacts on the mangroves and coastal marine ecosystems. The study also identified that women and non-poor

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participants exhibited higher risk perceptions of climate change effects on coastal marine ecosystems, as did the 19–29-year-old group. However, this younger age group displayed a lower risk perception concerning sea level rise's impact on mangrove ecosystems. Geographical context also influenced risk perception of sea level rise impact.

Alcantara et al. (2023) study expressed that Most participants recognized high impacts of anthropogenic drivers and climate change on coral reefs and seagrasses but perceived marine livelihood as having a lower impact. Risk perceptions were influenced by local temperature rise, excessive rainfall, and declining income, while education significantly impacted risk perception regarding the impacts on coral reefs and seagrasses. Furthermore, non-poor participants had notably higher risk perceptions than those from the poor demographic regarding the various factors affecting these ecosystems.

Siña et al. (2016) study shed light on how climate change is perceived within the governing bodies of Lima, offering insights into the municipalities' priorities and decision-making processes concerning public programs and initiatives. Although climate change and environmental concerns were acknowledged as vital for public health and safety, they were not consistently prioritized. The lack of emphasis on climate-related issues might be attributed to confusion about the causes and impacts of climate change, leading to oversight in decision-making processes.

Siña et al. (2016) study said that implementing strategies for adapting to and mitigating climate change could yield substantial long-term benefits for Lima's population, positively impacting both health and the economy. Addressing the gaps in understanding climate change and its associated mitigation and adaptation strategies could be facilitated by developing a tool. This tool could assist municipal officials in evaluating diverse strategies, providing a more informed and structured approach to addressing climate-related issues in their decision-making processes.

The local study identifies disparities in concern levels and response strategies between Barangay Officials and Residents regarding climate change in Northeast Catanduanes. Similarly, Siña et al. (2016) shed light on varying priorities and decision-making within Lima's governing bodies, pointing to confusion about climate change causes and impacts, affecting decision-making processes. Tailored communication and intervention strategies are highlighted in both studies to address nuanced differences and align with the differing preferences and priorities of distinct groups.

Moreover, Alcantara et al. (2023) delve into climate change awareness and risk perceptions in the coastal marine ecosystem of Palawan, revealing varying levels of awareness and risk perceptions among different demographic segments. They note influences such as experiences of climate-related events, socio-demographic characteristics, and geographical contexts on individuals' awareness and risk perceptions, echoing the importance of understanding local contexts and demographic differences in addressing climate change concerns highlighted in both the local study and Siña et al. (2016).

The Barriers to Communicate Climate Change

Ricart et al. (2022) research explores the relationship between farmers' perceptions of climate change and observed data through bibliometrics and content analysis. It identifies consolidated research areas such as perceived risk, crop vulnerability, forecasting use, and climate change awareness. However, significant gaps exist in conceptual discrepancies in defining 'normal' weather and 'drought,' limited access to quality data affecting farmers' perceptions, insufficient consideration of local knowledge, reliance on recent events in perception, and a geographical bias towards the Global South. To address these gaps, future research should define climate patterns, include socio-psychological analysis, and consider a broader global perspective. The study suggests that while both perceived and observed data have limitations, combining them offers a comprehensive understanding of climate change's impact on agriculture, with farmers' qualitative perceptions potentially complementing instrumental climate data in data-scarce areas.

Markowitz and Guckian (2018) concluded that Communicating Climate Change (CCC) is a challenging task with numerous pitfalls and few clear, universally applicable recommendations. However, recent years have seen notable progress in enhancing communication and outreach efforts. This advancement is partially credited to the dedicated work of social science researchers. They have delved into understanding the factors that drive or impede public engagement with climate change, exploring how different communication strategies and narratives influence people, and identifying effective forms of outreach to engage diverse audiences. Particularly encouraging is the ongoing diversification and experimentation in CCC. As researchers and communicators venture into new and innovative approaches, the potential to significantly transform public engagement and discourse around climate change, fostering better individual and collective decisions, continues to grow.

The current study highlights varied barriers to climate change communication, encompassing information gaps, financial concerns, and psychological factors. Addressing these requires tailored strategies that bridge the information gap and tackle financial, psychological, and behavioral hurdles. This aligns with the study by Ricart et al. (2022) that also stresses the insufficiency of information as a barrier, and Markowitz and Guckian (2018) note ongoing progress in diverse communication strategies, aligning with the need for tailored approaches identified in the present study to engage diverse audiences in climate change discourse effectively.

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3. Theoretical framework and hypothesis development

Two prominent theories that could serve as a theoretical framework for the study of communicating Climate Change in the Northeast of Catanduanes, Philippines, are:

3.1 Diffusion of Innovation Theory

This theory, proposed by Everett Rogers, focuses on how new ideas, innovations, or practices spread within a community or society. It could help understand the adoption of climate change communication strategies among the Barangay-Respondents. It categorizes individuals based on their readiness to adopt new ideas (innovators, early adopters, early majority, late majority, laggards) and considers factors like communication channels, social systems, and perceived benefits of adopting the innovation. This theory could display why certain demographic groupings within the Barangay might be more receptive to communicate climate change and which communication strategies might be more effective based on their characteristics (Van Houtven et al., 2023; Iqbal & Zahidie, 2022).

3.2 Social Learning Theory

This theory as established by Albert Bandura, stresses the importance of social interaction, observation, and modeling in the learning process. It advocates that people learn not just from their own experiences but also by observing others. Applied to the concern to communicate climate change, it could help understand how individuals in the Barangay learn about climate change and its implications through interactions within their social groups. This theory could help to identify influential figures within the community who could serve as effective communicators and also highlight the importance of peer-to-peer learning and community engagement in disseminating information about climate change (Ozer, 2022; Duffy, 2021).

The mentioned theories offer frameworks for understanding the diffusion and acceptance of new ideas (like climate change communication strategies) within a community and the role of social interactions in the learning process, which could be highly relevant in analyzing the concern and strategizing communicating climate change in the context of the Northeast of Catanduanes, Philippines.

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4. Methodology

4.1 Research Design

This study employs a mixed-methods approach (Johnson & Onwuegbuzie, 2004), combining quantitative and qualitative research methodologies through an online survey. The quantitative component aims to assess the degree of concern and the common strategies used for communicating climate change, as well as to identify barriers among the respondents from various barangays in the Northeast of Catanduanes. At the same time, the qualitative part involves an open-ended query directed at the barangay respondents, prompting them to elaborate on their chosen barriers to communicating climate change, enabling the emergence of prominent themes. This method facilitates a nuanced understanding of the complexities surrounding climate change communication within the specific context of the Northeast of Catanduanes. In essence, this study aligns with a descriptive research approach, capturing, analyzing, and interpreting current phenomena related to climate change communication within the targeted community. The data collection primarily utilizes an online survey questionnaire hosted on Google Forms.

The credibility of the responses provided by the barangay respondents is pivotal for the accuracy of the research findings. Consequently, employing descriptive research techniques is deemed the most appropriate design for this study (Siedlecki, 2020). The structure and methodology of this online survey draw inspiration from studies conducted by Sarathchandra and Haltinner (2021), Muto et al. (2020), and Rakhmanov and Dane (2020) that utilized online surveys in diverse contexts, particularly amid the backdrop of the COVID-19 pandemic. Sarathchandra and Haltinner's (2021) research employed an online survey to explore the influence of gender and education on environmental attitudes and climate change beliefs. Similarly, Muto et al. (2020) utilized an online platform with quota sampling to analyze the behavioral shifts among Japanese citizens during the early stages of the pandemic. Moreover, Rakhmanov and Dane (2020) conducted an online survey during the COVID-19 lockdown, targeting students self-isolating at home within the Nile University of Nigeria. These referenced studies provide valuable insights into the effective utilization of online surveys in diverse scenarios, offering a framework that resonates with the objectives and context of the current research in examining climate change communication within the Northeast of Catanduanes.

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4.2 Units of analysis/source of data/sampling

The term 'population' refers to a certain grouping of individuals, occurrences, or objects that are the focal point of study or consideration by the researcher. In the context of the present local study, the population under scrutiny comprises the barangay respondents from the Municipalities of Viga, Panganiban, and Bagamanoc. These respondents collectively represent the designated population for this research.

4.2.1 Sampling Procedure

The research universe consists of barangay respondents in the Northeast of Catanduanes. In observance of the measures of the Philippine Government in fighting COVID-19, the incidents required that the data gathering be carried out through an online survey.

Sharma and Tikka (2020) acknowledged certain limitations associated with online survey questionnaires, specifically in employing convenience sampling and gathering relatively small sample sizes that may deviate significantly from recommended research standards. However, they underscored the importance of refining the quality of online surveys, which mitigates the inherent limitations of convenience sampling and selection bias among responders. In alignment with the principles expounded by Sharma and Tikka (2020), the current study adopted a similar methodology, utilizing Google Forms for conducting an online survey to facilitate voluntary participation from respondents—outreach efforts involved using cell phones, email, and various social media platforms to engage potential participants. Given the inherent limitations in determining the exact number of potential participants in the digital environment, convenience and snowball sampling were deemed appropriate sampling methods for this study. Emerson (2020) and Sedgwick (2013) support the utilization of convenience sampling, defining it as the identification and classification of suitable individuals meeting the criteria for study respondents through any accessible means. Simultaneously, snowball sampling was employed, as participants were encouraged to recollect and share the electronic questionnaire link, acquiring the desired number of respondents.

The data collection process commenced on October 9, 2020, at 7:54:36 PM, concluding on October 24, 2020, at 3:00:14 PM, spanning 15 days. During this period, a total of 154 valid online responses were collected. This quantity of online responses is deemed sufficient considering the scope of the research population under investigation.

Table 1 presents the profile distribution of the barangay respondents, showing a diversified demographic landscape. Among them, females constitute a more significant proportion at 60.39% compared to males at 39.61%. Regarding age, the majority falls within the 29 and below category, comprising 51.30%, while 30-59-year-olds represent 41.56%, and those aged 60 and above are at 7.14%. Educational attainment showcases a higher percentage in technical and higher education at 65.58%, followed by individuals with elementary and secondary education at 24.03% and those with advanced education at 10.39%. Regarding their positions within the barangay, barangay residents make up a significant share at 83.77% compared to barangay officials at 16.23%. This categorization emphasizes the diverse structure of the respondents, reflecting various demographics and positions within the barangay.

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Table 1: Profile distribution of the barangay-respondent

Profile	Frequency	%
Sex		
Male	61	39.61
Female	93	60.39
Total	**154**	**100.00**
Age		
29 and below	79	51.30
30-59 age range	64	41.56
60 and above	11	7.14
Total		**100.00**
Educational Attainment		
Elementary and Secondary Education	37	24.03
Technical and Higher Education	101	65.58
Advanced Education	**16**	10.39
Total	**154**	**100.00**
Position in the Barangay		
Barangay Official	25	16.23
Barangay residents	129	83.77
Total	**154**	**100.00**

Source: Author´s elaboration

4.3 Data Collection/Instrumentation

The process of data collection in this study was influenced by the insights drawn from Hager et al.'s (2020) research, which noted the impracticality of a physical, paper-based questionnaire due to the prevailing COVID-19 pandemic and associated lockdown measures. As a result, reaching out to respondents was conducted through electronic means, such as emails and various social media platforms. This method aligns with the approach adopted in Geldsetzer's (2020) study, which utilized an online platform to assess public perceptions and knowledge about COVID-19 among a convenient sample of the general population.

In alignment with the methodologies employed by Hager et al. (2020) and Geldsetzer (2020), the present study also gathered research data from respondents residing in barangays within Northeast Catanduanes through online responses. These data underwent tabulation and subsequent statistical analysis to facilitate interpretations and discussions within the research. Moreover, the item statements from previous research studies explicitly addressing the communication of climate change concerns were revisited, simplified, and adapted to suit the constructs pertinent to the current investigation.

The finalized research instrument is accessible online, enabling outreach to potential respondents. This online approach holds particular advantages, especially in the context of the ongoing COVID-19 situation, where physical interaction is discouraged, as emphasized by Hager et al. (2020). The survey instrument initiates with a preamble to the respondents, elucidating the research's objectives and ensuring the confidentiality and ethical handling of the gathered data.

Strategic modifications were made to the research tool item statements to ensure they resonated well with the comprehension levels of the targeted respondents. The electronic version of the research instrument was available online for a 15-day duration, accessible through the link https://forms.gle/A9aVHxjY1Bntd4f39. The survey commences with a preliminary letter to the respondents, outlining the research's purpose and guaranteeing the confidentiality of the collected data while observing ethical considerations.

The questionnaire's structure encompasses sections devoted to profiling the barangay officials and residents in Northeast Catanduanes concerning sex, age, educational attainment, and position within the barangay. Subsequent segments involve presenting images accompanied by textual descriptions to gauge respondents' levels of concern regarding climate change and their intended methods of communicating or relaying the image's message to others. The questionnaire also encompasses queries about barriers to communicating climate change and solicits additional insights to elucidate these barriers among the respondents.

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Moreover, the questionnaire includes an Informed Consent Form to comply with ethical research standards. The author considered insights from Carlton and Jacobson (2016), Metag (2016), Vulturius et al. (2016), Kaesehage et al. (2014), and local experts involved in climate change initiatives at the writer's affiliated University to validate the questionnaire. The validation process confirmed the accuracy and relevance of the included questionnaire items.

The study utilized Cronbach's Alpha Coefficient to ensure the reliability of the questionnaires. It measures the internal consistency to establish the tool's reliability. The actual data, collected from 154 respondents through the survey, were subjected to Cronbach's Alpha Coefficient estimation. The results, as presented in Table 2, affirm the questionnaire's reliability as a research instrument.

Table 2. Reliability Analysis

Variables	No. of items	Cronbach's Alpha Coefficient (α)
The level of concern to communicate climate change among the respondent-barangay-residents in Northeast of Catanduanes	10	.905
The strategies adopted for communicating climate change among the respondent-barangay-residents in Northeast of Catanduanes	10	.751

Source: Author´s elaboration

The study data collection adhered strictly to ethical standards in administering the research process. The targeted respondents were duly informed about the research's nature and its procedural features, giving them the freedom to participate or decline participation in the study. The Catanduanes State University Ethics Committee has approved the execution of this study, underscoring its alignment with recognized ethical guidelines and regulations (Geneviève et al. 2018).

4.4 Data Processing

The data processing methods employed in this study encompassed various statistical tools, particularly Frequency count, Percentage, and weighted average mean. These statistical tools determined the level of concern about climate change and the common strategies for communicating climate change issues among the barangay respondents in Northeast Catanduanes. The assessment was categorized across crucial parameters, namely, A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation, with a focus on participants' demographic characteristics such as A) Sex, B) Age, C) Educational Attainment; and Position within the Barangay. Furthermore, the study examined the barriers obstructing effective communication about climate change among the barangay residents and officials in Northeast Catanduanes. The study involved a systematic tallying and ranking of these barriers, identifying the most significant to the least significant impediments to effective communication in the community.

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5. Results

Table 3, The level of concern and common strategies about the messages of Climate Change among the Barangay respondents in Northeast Catanduanes in terms of A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation according to their Sex

Item #	Item # in the ques-tionnaire	Type of pictures being communicated	Female (n=93)			Male (n=61)		
			Weighed Mean	Qualitative Response	Common Strategies	Weighed Mean	Qualitative Response	Common Strategies
		Climate Change Causes						
1	3	Unsegregated garbage	4.61	Very much concerned	I will refer or consult it to the proper authority.	4.48	Much Concern	I will refer or consult it to the proper authority.
2	4	Chopped wood	4.30	Much Concern		4.33	Much Concern	
3	5	Toxic gas emitted from industries	4.19	Much Concern		4.28	Much Concern	
4	7	Burning of garbage	4.34	Much Concern		4.36	Much Concern	
		Average Weighted Mean	**4.36**	**Much Concern**		**4.36**	**Much Concern**	
		Climate Change Effects						
5	1	Dry land due to drought	4.35	Much Concern	I will refer or consult it to the proper authority.	4.56	Very much concerned	I will refer or consult it to the proper authority.
6	2	Flooding due to extreme weather	4.63	Very much concerned		4.64	Very much concerned	
7	8	Forest fire	4.34	Much Concern		4.38	Much Concern	
		Average Weighted Mean	**4.44**	**Much Concern**		**4.52**	**Very much concerned**	
		Climate Change Mitigation						
8	6	Garbage Segregation	4.66	Very much concerned	I will tell it to my family and friends about the matter	4.49	Much Concern	I will tell it to my family and friends about the matter
9	9	Coastal Clean-up	4.60	Very much concerned		4.39	Much Concern	
10	10	Solar panel – renewable energy	3.94	Much Concern		4.13	Much Concern	
		Average Weighted Mean	**4.40**	**Much Concern**		**4.34**	**Much Concern**	

Source: Author's elaboration

The table 3 outlines the level of concern and common strategies about the messages of Climate Change among the barangay respondents in the Northeast of Catanduanes, segmented by sex and categorized into three key areas: A) Climate Change Causes, B) Climate Change Effects, and C) Climate Change Mitigation. The data includes the type of pictures being communicated, qualitative responses, common strategies, and the weighted mean for both female (93) and male (61) respondents.

The items under this category focus on the causes of climate change, including unsegregated garbage, chopped wood, toxic gas emitted from industries, and garbage burning. Both female and male respondents showed relatively high concern for these causes, with an average weighted mean of 4.36 for both genders. Common strategies expressed by respondents include referencing or consulting the issue with the proper authority.

This section addresses the effects of climate change, such as dry land due to drought, flooding due to extreme weather, and forest fires. Female respondents displayed slightly higher concern compared to male respondents in terms of weighted means: 4.44 for females and 4.52 for males. The qualitative response commonly involved referencing or consulting the matter with the proper authority.

Mitigation strategies discussed include garbage segregation, coastal clean-up, and solar panels for renewable energy. In this category, females tended to show slightly more concern (with an average weighted mean of 4.40) than males (with an average weighted mean of 4.34)—common strategies involved sharing the matter with family and friends.

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The results indicate a generally high level of concern among both female and male respondents regarding the causes, effects, and mitigation strategies related to climate change. Concerns are particularly notable regarding the effects of climate change, especially among female respondents. Both sexes tend to favor consulting or referencing issues with the proper authority. Additionally, in terms of mitigation strategies, both groups express a willingness to engage in actions and spread awareness among their social circles.

This data provides insights into the awareness and concern of barangay (local community) residents in the Northeast of Catanduanes regarding climate change issues, potentially informing targeted interventions or awareness campaigns to further educate and engage the community in mitigating climate change impacts.

Statistically, female respondents show marginally higher concern, particularly in addressing the effects of climate change, compared to their male counterparts. The implication of the observed sex discrepancy in concern about the effects of climate change is significant for targeted interventions. Understanding that females express slightly higher concern in this regard suggests the need for tailored strategies in engaging and mobilizing women in climate change initiatives, leveraging their specific interests and priorities to foster more effective community awareness and climate action.

The significant findings of the present study aligns with these global findings, showcasing a similar pattern: women tend to show higher concern about the personal impacts of climate change compared to men. The study by Zainulbhai in 2015 discovered that in wealthier nations, women are notably more worried about how climate change will affect them personally compared to men. This trend is consistent across developed countries like the U.S., Canada, Germany, and South Korea, where women view climate change as a serious problem, express concerns about potential personal harm, and advocate for significant lifestyle changes to address it. This sex gap in climate change concerns, observed both globally and locally, emphasizes the need to recognize and address these differences in crafting effective strategies and interventions for local climate action plans.

Further, the present local study mirrors global trends on the women show slightly higher concern about climate change effects. Aligning with Desrochers et al. (2019) and McCarthy & Citizen (2020), this finding underscores the need for targeted strategies. Leveraging women's marginally greater concern can drive more effective climate initiatives. Tailored approaches, acknowledging this gender discrepancy, offer opportunities to engage and mobilize women, fostering community awareness and impactful climate action.

Table 4, The level of concern and common strategies about the messages of Climate Change among the Barangay respondents in Northeast Catanduanes in terms of A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation according to their Age group

Item #	Item # in the Ques-tionnaire	Type of pictures being communicated	Age 29 and below (n=79)			Age 30 to Age 59 (n=64)			Age 60 and above (n=11)		
			Weighed Mean	Qualitative Response	Common Strategies	Weighed Mean	Qualitative Response	Common Strategies	Weighed Mean	Qualitative Response	Common Strategies
		Climate Change Causes									
1	3	Unsegregated garbage	4.52	Very much concerned	I will refer or consult it to the proper authority.	4.66	Very much concerned	I will refer or consult it to the proper authority.	4.27	Much Concern	I will tell it to my family and friends about the matter
2	4	Chopped wood	4.35	Much Concern		4.38	Much Concern		3.64	Much Concern	
3	5	Toxic gas emitted from industries	4.35	Much Concern		4.20	Much Concern		3.45	Little Concerned	
4	7	Burning of garbage	4.34	Much Concern		4.45	Much Concern		3.82	Much Concern	
		Average Weighted Mean	4.39	Much Concern		4.42	Much Concern		3.80	Much Concern	
		Climate Change Effects									
5	1	Dry land due to drought	4.41	Much Concern	I will refer or consult it to the proper authority.	4.48	Much Concern	I will refer or consult it to the proper authority.	4.36	Much Concern	I will refer or consult it to the proper authority.
6	2	Flooding due to extreme weather	4.54	Very much concerned		4.80	Very much concerned		4.36	Much Concern	
7	8	Forest fire	4.44	Much Concern		4.39	Much Concern		3.55	Much Concern	
		Average Weighted Mean	4.46	Much Concern		4.56	Very much concerned		4.09	Much Concern	
		Climate Change Mitigation									
8	6	Garbage Segregation	4.62	Very much concerned	I will tell it to my family and friends about the matter	4.66	Very much concerned	I will tell it to my family and friends about the matter	4.00	Much Concern	I will tell it to my family and friends about the matter
9	9	Coastal Clean-up	4.53	Very much concerned		4.59	Very much concerned		4.00	Much Concern	
10	10	Solar panel – renewable energy	4.15	Much Concern		4.06	Much Concern		2.73	Little Concerned	
		Average Weighted Mean	4.43	Much Concern		4.44	Much Concern		3.58	Much Concern	

Source: Author's elaboration

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Table 4 presents the varying levels of concern and common strategies about the messages of Climate Change among respondents in different age brackets regarding climate change causes, effects, and mitigation strategies.

For Climate Change Causes, Across age groups, there is a consistently high concern for unsegregated garbage as a cause of climate change, with the highest concern among the 30 to 59 age group. Concern for chopped wood and toxic gas emitted from industries is relatively consistent, but the younger age group shows higher concern for toxic gas. The response "I will tell it to my family and friends about the matter" is notably more common among respondents aged 60 and above.

For Climate Change Effects: All age groups exhibit significant concern about the effects of climate change, particularly extreme weather-related issues like drought, flooding, and forest fires. Notably, respondents aged 30 to 59 express the highest concern across these categories.

For Climate Change Mitigation, Garbage segregation and coastal clean-up garner high concern across all age groups. However, the younger age group shows more heightened concern for solar panel usage as a form of renewable energy.

The data suggests that different age groups prioritize and perceive climate change causes, effects, and mitigation strategies differently. Younger respondents are more inclined towards specific mitigation strategies like renewable energy solutions, while the older age group leans towards interpersonal communication for addressing causes.

The implication of the notable prevalence of the response "I will tell my family and friends about the matter" among respondents aged 60 and above suggests a reliance on interpersonal communication and social networks within this age group. This highlights the potential for leveraging familial and social circles as essential channels for disseminating information and initiating collective action toward addressing climate change. Harnessing this inclination could be an effective means of spreading awareness and fostering community engagement among older generations.

Further, the research data illustrates notable distinctions in concerns regarding climate change across different age groups. Individuals aged 30 to 59 generally exhibit heightened levels of apprehension about the causes and effects of climate change compared to younger and older demographics. Moreover, the middle age group demonstrates a stronger inclination toward proactive strategies, particularly emphasizing concerns and actions related to mitigating climate change effects. Understanding these divergences is pivotal for implementing targeted interventions that resonate with the specific priorities of each age group optimizing efforts to address climate change concerns effectively.

The implications of these significant age-based differences in concerns about climate change are crucial. Understanding the varied priorities among age groups allows for more effective and targeted approaches to address climate change issues. Implementing age-specific programs and communication strategies could foster greater engagement and participation, as different generations have distinct inclinations toward causes, effects, and mitigation strategies.

Tailored interventions and communication strategies could enhance engagement, considering the varying priorities and concerns across different age levels. The said approach can maximize the impact of initiatives by aligning them more closely with the specific concerns and interests of each age demographic, thus facilitating a more comprehensive and impactful response to climate change challenges.

The present local study disparities in climate change concerns across age groups aligned with the insights of various authors in this field. Ballew et al. (2019) similarly note heightened worry among younger Americans (ages 18 to 34) compared to their older counterparts, aligning with the local study's findings of heightened apprehension in younger demographics. Moreover, Ballew et al. highlight the uncertainty surrounding younger individuals' engagement with climate change, paralleling the local study's identification of uncertainty regarding younger age groups' active involvement. Frumkin et al. (2012) underscore the diversity of attitudes among older individuals, mirroring the local study's recognition of varied concerns among different age brackets. Additionally, the emphasis on tailored interventions in the present study is in line with Frumkin et al.'s suggestion for customized strategies to engage older generations effectively. Funk (2021) accentuates political discrepancies among younger age groups regarding climate change, which resonates with the local study's identification of political variances within younger demographics. The present study's focus on tailored interventions aligns with Funk's insights on the need for age-specific strategies in addressing climate change concerns across different generational groups.

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Table 5, The level of concern and common strategies about the messages of Climate Change among the Barangay respondents in Northeast Catanduanes in terms of: A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation according to their Educational Attainment

Item #	Item # in the ques-tionnaire	Type of pictures being communicated	Elementary and Secondary Education (n=37)			Technical and Higher Education (n=101)			Advanced Education (n=16)		
			Weighed Mean	Qualitative Response	Common Strategies	Weighed Mean	Qualitative Response	Common Strategies	Weighed Mean	Qualitative Response	Common Strategies
		Climate Change Causes									
1	3	Unsegregated garbage	4.24	Much Concern	I will refer or consult it to the proper authority.	4.61	Very much concerned	I will refer or consult it to the proper authority.	4.94	Very much concerned	I will refer or consult it to the proper authority.
2	4	Chopped wood	4.03	Much Concern		4.40	Much Concern		4.44	Much Concern	
3	5	Toxic gas emitted from industries	3.95	Much Concern		4.29	Much Concern		4.50	Very much concerned	
4	7	Burning of garbage	4.00	Much Concern		4.40	Much Concern		4.88	Very much concerned	
		Average Weighted Mean	4.05	Much Concern		4.42	Much Concern		4.69	Very much concerned	
		Climate Change Effects									
5	1	Dry land due to drought	4.27	Much Concern	I will refer or consult it to the proper authority.	4.44	Much Concern	I will refer or consult it to the proper authority.	4.81	Very much concerned	I will refer or consult it to the proper authority.
6	2	Flooding due to extreme weather	4.59	Very much concerned		4.61	Very much concerned		4.88	Very much concerned	
7	8	Forest fire	4.00	Much Concern		4.47	Much Concern		4.50	Very much concerned	
		Average Weighted Mean	4.29	Much Concern		4.50	Very much concerned		4.73	Very much concerned	
		Climate Change Mitigation									
8	6	Garbage Segregation	4.19	Much Concern	I will tell it to my family and friends about the matter	4.67	Very much concerned	I will tell it to my family and friends about the matter	5.00	Very much concerned	I will tell it to my family and friends about the matter
9	9	Coastal Clean-up	4.14	Much Concern		4.58	Very much concerned		5.00	Very much concerned	
10	10	Solar panel – renewable energy	3.57	Much Concern		4.09	Much Concern		4.56	Very much concerned	
		Average Weighted Mean	3.96	Much Concern		4.45	Much Concern		4.85	Very much concerned	

Source: Author´s elaboration

The Table 5 dataset presents a compelling correlation between levels of educational attainment and attitudes toward climate change, delineating distinct variations in the levels of concern and perceptions of efficacy across diverse educational groups.

Regarding Concerns about the Causes of Climate Change: The data indicates that individuals with varying levels of education exhibit differing degrees of concern. The respondents with Basic Education display an average concern weighted mean of 4.05, while Technical and Higher Education present a higher average concern weighted mean of 4.42. Notably, Advanced Education records the highest average concern weighted mean of 4.69. The discernible disparity in concern levels, particularly the higher averages within the more advanced educational qualification, suggests a clear relationship between higher education levels and heightened apprehension regarding the causes of climate change. This means a potential implication: individuals with advanced educational backgrounds tend to demonstrate greater sensitivity and concern toward the multifaceted causes of climate change compared to those with basic education levels.

On the Perception of Climate Change Effects: A similar pattern in concern levels emerges across educational strata. The respondents with Basic Education report an average concern weighted mean of 4.29, while those with Technical and Higher

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Education demonstrate a slightly higher average concern weighted mean of 4.50. Respondents with Advanced Education exhibit the most elevated concern with an average concern weighted mean of 4.73. This consistent trend implies that individuals with higher educational achievements are inclined to manifest increased concern regarding the effects of climate change. This suggests a potential implication: those with more advanced educational backgrounds are more mindful of and responsive to the potential impact and consequences of climate change.

Regarding Climate Change Mitigation: Regarding the perceived effectiveness of mitigation strategies, the data delineates varying perspectives across educational strata. Respondents with Basic Education record an average effectiveness weighted mean of 3.96, while those with Technical and Higher Education report a slightly higher average of 4.45. Advanced Education reflects the highest average weighted mean of 4.85. This trend implies that individuals with advanced educational backgrounds tend to perceive climate change mitigation strategies as more effective compared to those with basic educational levels. The finding suggests that higher Education may contribute to a more favorable evaluation of potential solutions for addressing climate change issues.

The data underscores a clear positive correlation between higher educational attainment and increased concern for, as well as the perceived effectiveness of, strategies related to climate change. This underlines that educational initiatives to raise awareness and knowledge about climate change could lead to a more informed and responsive populace, particularly among those with higher educational achievements. Furthermore, policy interventions and educational programs tailored to address climate change concerns may benefit from targeting individuals across various educational levels to ensure an inclusive and comprehensive approach to combating climate change.

The present local study highlights a strong link between higher Education and increased concern for and perceived effectiveness of strategies related to climate change. This aligns with insights from Ambasz, Gupta, and Patrinos (2023), who reviewed the interconnection between human development, especially Education, and its impact on pro-environmental behavior concerning climate change. They emphasize the role of Education in fostering environmentally conscious behaviors but note the challenge of establishing a clear causal relationship between Education and pro-environmental attitudes.

Zaval and Cornwell (2017) emphasize the critical role of Education and behavioral science in promoting pro-environmental action, aligning with the local study's focus on the importance of educational initiatives to raise awareness about climate change. They highlight the impact of behavioral approaches, such as appeals to social norms, in influencing environmentally responsible actions. Similarly, Ledley, Rooney-Varga, and Niepold (2017) underscore the vital connection between Education and addressing climate change, advocating for an education approach that transcends scientific knowledge and integrates various disciplines. They stress that Education is crucial in fostering knowledgeable and responsible leadership across sectors and empowering proactive citizen engagement. These studies collectively support the local study's emphasis on the need for educational programs tailored to address climate change concerns across various educational levels to foster an informed and responsive populace.

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Table 6, The level of concern and common strategies about the messages of Climate Change among the barangay residents and officials in Northeast Catanduanes in terms of: A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation

Item #	Item # in the ques-tionnaire	Type of pictures being communicated	Barangay Officials (n=25)			Barangay residents (n=129)		
			Weighed Mean	Qualitative Response	Common Strategies	Weighed Mean	Qualitative Response	Common Strategies
		Climate Change Causes						
1	3	Unsegregated garbage	4.76	Very much concerned	I will refer or consult it to the proper authority.	4.52	Very much concerned	I will refer or consult it to the proper authority.
2	4	Chopped wood	4.44	Much Concern		4.29	Much Concern	
3	5	Toxic gas emitted from industries	4.04	Much Concern		4.26	Much Concern	
4	7	Burning of garbage	4.52	Very much concerned		4.32	Much Concern	
		Average Weighted Mean	4.44	Much Concern		4.35	Much Concern	
		Climate Change Effects						
5	1	Dry land due to drought	4.56	Very much concerned	I will refer or consult it to the proper authority.	4.41	Much Concern	I will refer or consult it to the proper authority.
6	2	Flooding due to extreme weather	4.68	Very much concerned		4.63	Very much concerned	
7	8	Forest fire	4.32	Much Concern		4.36	Much Concern	
		Average Weighted Mean	4.52	Very much concerned		4.47	Much Concern	
		Climate Change Mitigation						
8	6	Garbage Segregation	4.88	Very much concerned	I will refer or consult it to the proper authority.	4.53	Very much concerned	I will tell it to my family and friends about the matter
9	9	Coastal Clean-up	4.64	Very much concerned		4.50	Much Concern	
10	10	Solar panel – renewable energy	3.80	Much Concern		4.05	Much Concern	
		Average Weighted Mean	4.44	Much Concern		4.36	Much Concern	

Source: Author´s elaboration

The presented data in Table 6 offers a comprehensive insight into the attitudes and common strategies related to climate change messages among respondent-barangay residents in Northeast Catanduanes, categorized by their roles as either Barangay Officials or Barangay Residents. The findings reveal varying levels of concern and responses towards three distinct aspects: Climate Change Causes, Climate Change Effects, and Climate Change Mitigation. The sample size of Barangay Officials, comprising 25 individuals, showcased higher concern levels across all three categories, often expressing a strong willingness to refer or consult relevant authorities regarding climate change causes and effects. On the other hand, the larger group of Barangay Residents (n=129) displayed slightly lower but still substantial levels of concern regarding these issues. There is a noteworthy convergence in concern levels between the two groups concerning the causes and effects of climate change. However, the approach to climate change mitigation strategies varied significantly. Barangay Officials tended to emphasize referring or consulting authorities, whereas Barangay Residents were more inclined to disseminate information within their social circles.

The data elucidates not only the disparities in concern levels and response strategies between Barangay Officials and Residents but also highlights the collective awareness and acknowledgment of the gravity of climate change issues within their locality. Despite differing approaches, both groups recognize the urgency of addressing climate change causes and effects, albeit with nuanced differences in the perceived efficacy of mitigation strategies. This variation underscores the importance of tailored communication and intervention strategies, particularly in the realm of climate change mitigation, to align with the differing preferences and priorities of these distinct groups. Such insights are pivotal in formulating and implementing community-specific initiatives aimed at effectively addressing and mitigating the impact of climate change within Northeast Catanduanes.

The local study identifies disparities in concern levels and response strategies between Barangay Officials and Residents regarding climate change in Northeast Catanduanes. Similarly, Siña et al. (2016) shed light on varying priorities and decision-

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making within Lima's governing bodies, pointing to confusion about climate change causes and impacts, affecting decision-making processes. Tailored communication and intervention strategies are highlighted in both studies to address nuanced differences and align with the differing preferences and priorities of distinct groups.

Moreover, Alcantara et al. (2023) delve into climate change awareness and risk perceptions in the coastal marine ecosystem of Palawan, revealing varying levels of awareness and risk perceptions among different demographic segments. They note influences such as experiences of climate-related events, socio-demographic characteristics, and geographical contexts on individuals' awareness and risk perceptions, echoing the importance of understanding local contexts and demographic differences in addressing climate change concerns highlighted in both the local study and Siña et al. (2016).

Table 7, The Barriers to Climate Change Communication.

The Barriers	Frequency (n=154)
Lack of information	82
Cost/Financial expense	25
Lack of time	17
Inconvenience/discomfort	16
No idea	9
Lack of discipline	2
Close-mindedness of other people	1
Residents are given information but they take it for granted	1
Scared or afraid	1

Source: Author´s elaboration

The researcher collected the research data from 154 respondents. From a quantitative perspective, the frequency distribution of reasons or barriers to effective climate change communication can be summarized as follows:

The data obtained from 154 respondents highlights a spectrum of reasons or barriers to effective climate change communication. Among the most prevalent obstacles, the primary hindrance identified by 82 respondents was the "Lack of Information." This denotes a critical need for more accessible, clear, and comprehensive information dissemination on climate change. The second most cited barrier was "Cost/Financial Expense," with 25 respondents expressing concerns about the economic implications of adopting sustainable practices. Additionally, "Lack of Time" was noted by 17 respondents as a barrier, signifying the challenge of time allocation for engaging with climate change discourse. Less frequently mentioned barriers included "Inconvenience/Discomfort" identified by 16 respondents, "No Idea" by nine respondents, "Lack of Discipline" by two respondents, and equally low frequencies of "Close-Mindedness of Other People," "Residents Taking Information for Granted," and "Scared or Afraid" each expressed by one respondent. These lower-frequency barriers imply varied individual and psychological obstacles that contribute to the challenge of effectively communicating the message of climate change.

The highest frequency of responses centered around "Lack of Information." This highlights a crucial aspect where individuals may need sufficient knowledge or a comprehensive understanding of climate change. It indicates the need for more accessible, clear, and accurate information on climate change. The lack of awareness might be due to the complexity of the subject, a shortage of credible sources, or ineffective communication strategies.

The second most cited barrier, "Cost/Financial Expense," indicates that some individuals perceive sustainable actions or eco-friendly practices as financially burdensome. This perception might discourage their engagement in climate-friendly behaviors. It reflects a need for policies or solutions that make sustainable choices more affordable and economically feasible for a broader demographic.

The lower frequency responses, such as "Inconvenience/Discomfort," "Lack of Time," "No Idea," "Lack of Discipline," "Close-Mindedness of Other People," "Residents Taking Information for Granted," and "Scared or Afraid," while fewer in number, also shed light on various personal and psychological barriers. These barriers could be individual-centric, reflecting the unique challenges individuals face in accepting, understanding, or acting upon climate change information.

From a comprehensive standpoint, the findings suggest a multifaceted nature of barriers to effective climate change communication. While lack of information and financial concerns dominate the responses, the diversity of reasons, even in lower frequencies, indicates a range of psychological, social, and economic barriers that impede effective communication on this crucial issue.

Strategies must be multifaceted, addressing not only the information gap but also the financial, psychological, and behavioral barriers to improve climate change communication. Crafting tailored communication approaches, promoting the

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affordability of eco-friendly practices, and addressing individual concerns are critical steps toward more effective climate change communication and action.

The further details to explain the barriers to communicating Climate Change

The study managed a qualitative analysis of respondents' perspectives on barriers to Climate Change Communication. Respondents were prompted with an open-ended query, seeking additional reasons supporting their chosen barriers to Climate Change Communication.

The results revealed several prominent themes. Firstly, the inadequacy of information and awareness emerged as a significant obstacle, encompassing factors such as insufficient knowledge of climate change consequences, limited access to information due to various reasons like time constraints, disinterest, or educational barriers, and inadequate communication channels. Financial constraints were identified as another crucial impediment, encompassing both personal and governmental levels, where a lack of funds hindered efforts to address climate change. Communication and education hurdles were evident, reflecting challenges in effectively relaying messages due to a lack of training or discomfort in addressing the issue, as well as limited time and overlapping responsibilities. Social and cultural factors played a role, with self-centered attitudes, fear of speaking out, and limited government dissemination except during crises, all contributing to the hindrance. Additionally, other factors, such as the "new normal" affecting routines, lack of monitoring due to personal engagements, and the need for more comprehensive educational programs, were identified. The findings underscored the issue's complexity, emphasizing the necessity for a multi-pronged strategy that integrates education, awareness, information accessibility, financial resources, and a transformative shift towards environmental consciousness to address the challenges of climate change communication effectively.

The findings of the present study emphasize the multifaceted nature of barriers to climate change communication, including information gaps, financial concerns, and psychological and behavioral obstacles. The tailored strategies are essential, addressing not only the information gap but also economic, psychological, and behavioral obstacles to enhance climate change communication. This comprehensive approach can improve climate change awareness and engagement.

In a related study by Ricart et al. (2022), the inadequacy of information and awareness was identified as a significant barrier to climate change understanding, which aligns with the findings of the present study regarding the "Lack of Information" barrier. Floranza's (2021) study on Barangay Governance emphasizes consistent monitoring and assessment of barangay performance that may indirectly lead to highlighting the need for a structured approach in addressing the "Lack of Information" barrier. This aligns with Markowitz and Guckian's (2018) assertion that ongoing progress in climate change communication involves exploring various communication strategies to engage diverse audiences effectively. Both perspectives indirectly address the need for comprehensive and tailored approaches to overcoming the "Lack of Information" barrier by emphasizing the importance of continuous evaluation and utilizing diverse communication strategies to bridge information gaps and effectively communicate climate-related concerns to the communities.

6. Discussion and conclusions

Looking into the level of concern and common strategies to communicate Climate Change among the Barangay respondents in Northeast Catanduanes in terms of A) Climate Change causes, B) Climate Change effects, and C) Climate Change mitigation according to their A) Sex; B) Age; C) Educational Attainment; and Position in the Barangay. The Diffusion of Innovation Theory displays why specific demographics within a particular community might be more interested in communicating climate change and which communication strategies might be more successful grounded by their attributes.

Regarding the concern and strategies about Climate Change messages among Northeast Catanduanes barangay respondents by sex, covering causes, effects, and mitigation. Both females (93) and males (61) express notable concern. Females slightly prioritize effects, while males show comparable concern across causes, effects, and mitigation. Strategies involve consulting authorities and sharing information with family and friends. This gender discrepancy in climate concern aligns with global trends, emphasizing the need for targeted interventions to engage women effectively in climate initiatives. Tailoring strategies based on this gender difference offer opportunities for impactful community awareness and action.

When grouped by age, regarding climate change causes, effects, and mitigation. Younger respondents prioritize renewable energy, while the older group favors interpersonal communication to tackle causes. The prevalence of "I will tell my family and friends about the matter" among the older age group suggests using social circles to disseminate information. Individuals aged 30 to 59 show heightened concern for climate issues. Understanding these distinctions across age groups is pivotal for tailored interventions to address climate change effectively. The findings stressed the age-based disparities and emphasized the need for age-specific strategies in climate change initiatives.

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This further illustrates educational attainment's correlation with attitudes toward climate change among Barangay respondents in Northeast Catanduanes. Higher education levels correspond to increased concern and perceived effectiveness of climate change responses. Individuals with advanced education display notably higher concern regarding climate change causes and effects, as well as a stronger belief in the efficacy of mitigation strategies compared to those with basic education. This signifies the potential impact of higher education in raising awareness and fostering more informed responses to climate change challenges. Insights from Ambasz, Gupta, and Patrinos (2023), Zaval and Cornwell (2017), and Ledley, Rooney-Varga, and Niepold (2017) support this, emphasizing education's pivotal role in promoting environmentally conscious behavior and addressing climate change concerns. They advocate for tailored educational programs across different educational levels to nurture informed and engaged communities.

The study further displays the concern and the common strategies toward climate change messages among Barangay Residents and Officials in Northeast Catanduanes. Barangay Officials (25 individuals) showed higher concern across Climate Change Causes, Effects, and Mitigation and were willing to consult authorities. The larger group of Residents (129 individuals) displayed slightly lower but still significant concern levels. Both groups aligned in concern for causes and effects, but Officials leaned towards consulting authorities, while Residents favored sharing information within their social circles for mitigation. This suggests a need for tailored strategies, acknowledging different preferences between these groups. Insights from this local study align with similar findings by Siña et al. (2016) and Alcantara et al. (2023), emphasizing tailored approaches due to differing priorities and demographics' influence on climate change awareness and strategies.

Further, the barriers to communicating Climate Change among the Barangay respondents and what further details explain the barriers to communicating Climate Change. The data from 154 residents reveals primary barriers to Climate Change Communication. "Lack of Information" is the most critical issue, indicating the need for more precise and accessible climate knowledge. "Cost/Financial Expense" follows, showing concerns about the financial burden of sustainable actions. Lower-mentioned barriers like "Inconvenience/Discomfort," "Lack of Time," and personal obstacles highlight individuals' diverse challenges. The present study's findings emphasize a need for varied strategies, not only addressing information gaps and financial concerns but also individual, psychological, and social barriers. Tailored approaches, affordable eco-friendly options, and addressing personal concerns are crucial for better communication and action on Climate Change.

The study further examined barriers to communicating Climate Change. Respondents highlighted several vital obstacles. Need for more information and awareness, financial limitations, communication and education challenges, and social factors emerged. The complexity suggests a diverse strategy, integrating education, awareness, accessible information, financial resources, and a shift in environmental consciousness. In enhancing the concern to communicate Climate Change, targeted approaches are necessary, addressing the information gap, financial matters, and psychological barriers. Similar findings in related studies stress the ongoing need for varied communication strategies to engage diverse audiences effectively, consonant with the Social Learning Theory where locals learn not just from their own experiences but also by observing others to enhance concern to communicate Climate Change.

7. Recommendation

The study furnishes practical and community-centric solutions to enhance the level of concern, strategies, and overcoming barriers associated with communicating climate change within the local community.

First, the study suggests a Sex-Focused Engagement by Organizing local meetings specifically for women and men, addressing their respective concerns about climate change. Encourage women-led programs and men's groups to take action on the issues they feel most passionate about.

Second, the researcher proposes Age-Specific Efforts by developing fun educational programs for younger individuals, promoting the importance of nature and environmental conservation through games and interactive activities. Encourage elders to share their wisdom in community meetings, highlighting the importance of protecting the environment based on their experiences.

Third, Educational Drive, through engaging advanced education students in hands-on projects, like tree planting or sustainable community gardens, to promote environmental consciousness. It is recommended to produce engaging, age-appropriate content, like comics or short videos, to distribute to local schools and libraries, educating various age groups about climate change.

Fourth, the study may offer customized Barangay Plans by facilitating regular meetings involving officials and community members, emphasizing shared solutions to address climate issues unique to their barangay. It is suggested to utilize multiple communication tools like local radio and community events to effectively convey climate concerns, tailoring messages for residents and officials.

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Fifth, tackle communication Challenges by establishing community hubs offering information on sustainable living practices and local eco-friendly resources to increase awareness. It is suggested to create a system where community members can share eco-friendly goods, reducing costs and enhancing accessibility. Additionally, it will introduce support services for those facing mental health challenges due to climate anxiety.

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Assessing Building Sustainability: Economic, Environmental, and Social Dimensions Explored

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Abstract

This research focuses on the importance of impact assessment in the construction sector, aligning with the United Nations' 2030 agenda for sustainable urban development. It emphasizes the need to incorporate economic, environmental, and social considerations into these assessments. A bibliometric analysis reveals an escalating interest in this field, particularly since 2015, illustrating the significant contribution of academic research to disseminating knowledge in this area. The paper highlights the crucial role of integrating these three sustainability dimensions in evaluating building impacts. Life cycle analysis, sustainable material use, and environmental impact assessments emerge as thematic clusters. Geographically, China stands out as the leading contributor to the topic, followed by the USA, Italy, and the UK, suggesting profound cross-country collaborations. The analysis indicates an inverse relationship between renovation costs and sustainability, emphasizing the need to balance demands and costs during the construction and renovation. Within this context, the Life Cycle Assessment (LCA) stands out as the favored measurement model, accounting for various inputs and outputs, including environmental, social, and economic impacts. European policies champion building sustainability, advocating for circular economy approaches and CO2 emission reductions. Independent committees or agencies are perceived as a catalyst for sustainability in building processes. However, the study acknowledges limitations, including exclusive reliance on the Scopus database and potential subjectivity in thematic analysis. Future research could benefit from additional databases like Web of Science, advanced thematic analysis software, and comprehensive case studies. Further engaging consumers in the building sustainability perspective may also present a promising research avenue.

Keywords: Impact Assessment; Sustainability; Buildings; Construction; Life Cycle; Circular Economy

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1. Introduction

Construction is one of the key sectors in the global economy, but its growth and development significantly impact the environment and society (Díaz-López et al., 2021). Building impact assessment has become an essential component in the design and construction of new buildings and in the management of existing ones (Ameen et al., 2015). This practice aims to assess the economic, environmental, and social effects associated with buildings, seeking to balance economic sustainability, environmental responsibility, and social well-being (Zahra & Wright, 2016). Over the years, awareness of global environmental issues and challenges related to urbanization has pushed governments, businesses, and construction industry professionals to carefully consider how building projects affect the surrounding environment and community. Considering this, advanced methodologies in building impact assessment, such as life cycle analysis and green building certifications, have emerged as key strategies to promote sustainability in the construction sector. These approaches focus on minimizing negative impacts and creating a positive legacy in urban development, thus aligning with the broader objectives of sustainable development (Khasreen et al., 2009). It follows that building impact assessment can be a tool to identify and mitigate negative impacts and maximize benefits in terms of economic, social, and ecological sustainability (Pope et al., 2004). Furthermore, integrating smart technologies in building design and management is revolutionizing how we approach environmental sustainability and energy efficiency. This technological shift enhances the performance of buildings and contributes significantly to urban sustainability, offering a path towards achieving the ambitious targets set by the United Nations for sustainable urban environments (Secinaro, Brescia, et al., 2022). Particularly considering the main international frameworks, the United Nations' 2030 agenda has highlighted goal 11 as primary: to make cities and human settlements inclusive, safe, resilient, and sustainable (United Nations, 2015).

This article aims to gather the main literature related to building impact assessment, highlighting its role in promoting sustainability. To do this, the authors conducted a bibliometric analysis on a sample of 129 documents, answering the following research questions:

RQ1: What key bibliometric data and thematic insights pertain to the field of building impact assessment?
RQ2: What are the unique characteristics of building impact assessment?

To our knowledge, no other articles aim to define the main bibliometric and thematic parameters related to building impact assessment using Bibliometrix (Aria & Cuccurullo, 2017). This study is a literature review (SLR) on building impact assessment that uses a hybrid approach that combines the SLR with bibliometric analysis in five phases: study design, data collection, data analysis, data visualization, and interpretation (Lanzalonga et al., 2023; Sadraei et al., 2022). The research considers multidisciplinary studies and offers a comprehensive view of the state of the art on the subject to understand the logics that underlie the growing interest in building impact assessment.

The article contributes to collecting bibliometric information that considers economic, environmental, and social aspects to guide informed decisions in the construction sector. Furthermore, the document provides a framework for understanding the elements characterizing the building impact assessment.

2. Methodology

This study aims to conduct a Structured Literature Review (SLR) on the impact assessment of buildings (Massaro et al., 2016). The methodology is suitable for systematizing the flows of literature that, to date, are partially understood by international scholars (Biancone et al., 2020). Consequently, this study uses a hybrid approach to conduct an SLR with bibliometric analysis (Abarca et al., 2020), adopting a workflow mapping methodology through five phases (Zupic & Čater, 2015): (i) study design, (ii) data collection, (iii) data analysis, (iv) data visualization, and (v) interpretation.

2.1 Study design

The research aims to identify research questions and the theoretical model for observing the impact assessment of buildings in the literature (Biancone et al., 2022). Although initially specific to the accounting sector, the SLR methodology applied to the sample of articles was extended to the broader field of management due to its reliable research protocol (de Bem Machado et al., 2021; Secinaro et al., 2020). Therefore, a joint bibliometric and coding method can help researchers identify the essential variables of the research scope in a short time. The authors conducted an SLR through a deep and reliable review of knowledge in the study domain and identified areas for future research (Piontek et al., 2021; Uluyol et al., 2021). It is possible to analyze

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multidisciplinary studies through metadata analysis (Secinaro, Brescia, et al., 2022). This research aims to consider within the cluster not only articles closely related to the business model concept but also those dealing with food industry production. In this sense, the research offers a holistic view of the state of the art of the topic and allows grouping the literature on the subject by identifying appropriate sections to advance research in the study by offering a research agenda (Secinaro, Calandra, et al., 2022; Ştefănescu et al., 2021).

2.2 Data collection

In September 2023, the data collection process began using the Scopus database through the search key "impact assessment" AND "building". The multidisciplinary database is considered suitable for researchers in economics and management (Okoli & Schabram, 2010). The primary results obtained were 2,567 documents. Despite the known interdisciplinary nature of the topic (Saber & Silka, 2020), it is consistent with the theoretical reference concept to consider only articles related to the business and management field. Moreover, only articles from peer-reviewed journals in English were considered (Brescia et al., 2021).

To ensure we did not miss any essential data, we manually searched the references of all selected articles, using backward and forward snowballing (Brzica, 2023; Christofi et al., 2021). In this way, we ensured not to leave out some of the most relevant articles in the document selection process. After this phase, the researchers manually downloaded all article pdfs to create codes and the subsequent research cluster analysis (Dal Mas et al., 2019; Foschi et al., 2023).

The data collection of this research is consistent with the SPAR-4-SLR guidelines by (Paul et al., 2021) (Figure 1). According to Moher (2009), mapping a systematic review protocol is essential to overcome biases in document selection. Consequently, 129 articles passed the restrictive criteria. The study used Bibliometrix, a statistical package in R-Studio (Aria & Cuccurullo, 2017). This package allows analyzing bibliometric information, including authors, citations, sources, and keywords.

2.3 Data Analysis

Several analysis tools were applied to answer the research questions and the study's objectives. Firstly, to answer RQ1, we used Bibliometrix R-Package and the biblioshiny app, which is increasingly used in scientific literature to provide a state of the art of knowledge flow under study (Aria & Cuccurullo, 2017; Vaska et al., 2021). Moreover, to answer RQ2 and inspire constructive criticism, we used the Atlas.ti cloud version software to create specific codes to map the background and methods used by authors. The software is suitable for verifying the consistency between codes and analyzed documents (Hwang, 2008; Talanquer, 2014). Lastly, we used the Vos Viewer software to create the cluster map to show conceptual maps of information dissemination (Van Eck & Waltman, 2011). The following sections provide insights on data visualization and interpretation. Finally, the theoretical and practical implications related to future research lines are found in the conclusions section.

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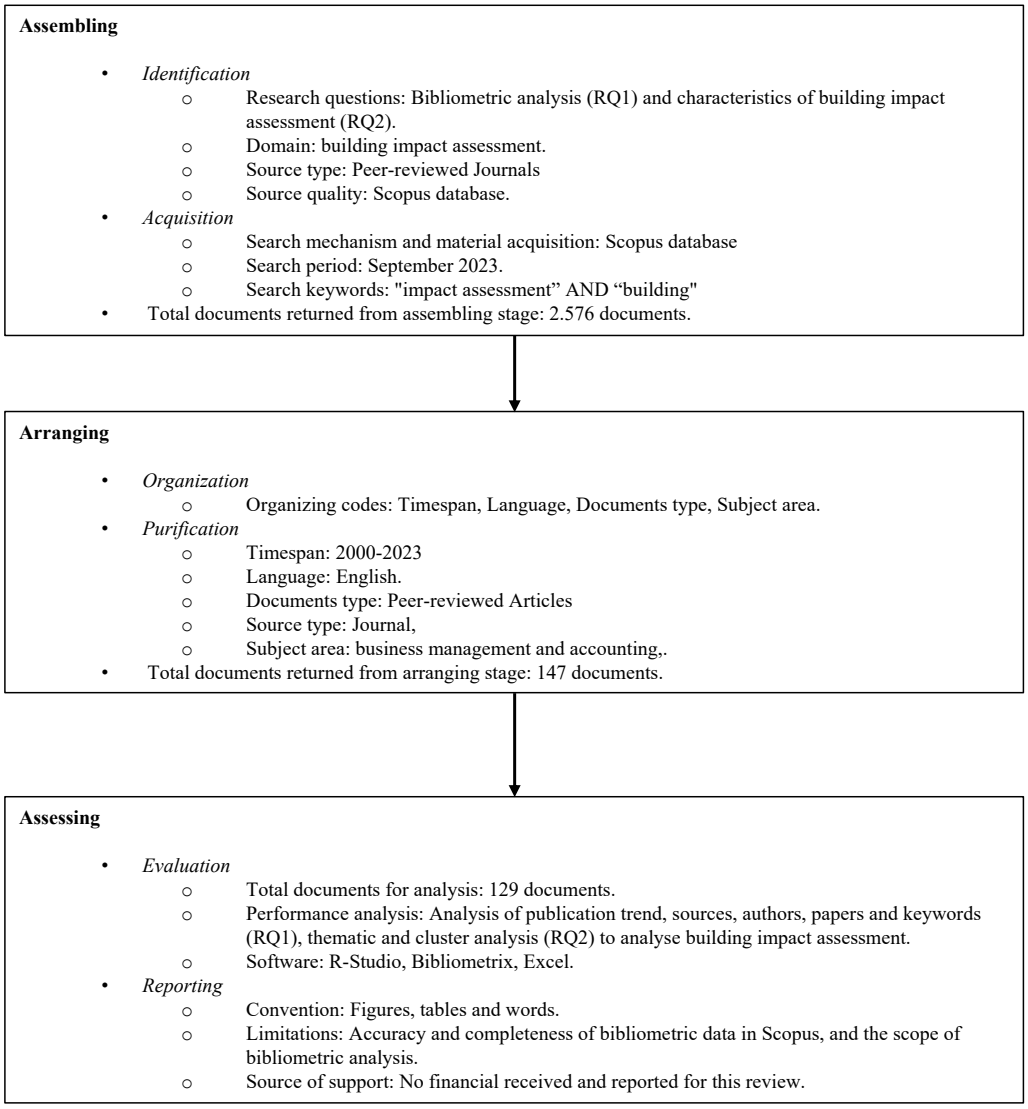
Figure 1. Data collection methodology



Source: Authors' elaboration consistent with the SPAR-4-SLR guidelines by (Paul et al., 2021)

3. Results

This section aims to delve into the results of the sample. Firstly, Table 1 describes the temporal characteristics of the articles considered to understand the state of the art of property assessment. Specifically, the time span ranges from 2000 to 2023, including 45 documentary sources for the entire sample. There are 129 documents, and publications' average annual growth rate is 10.53%. The topic is of significant interest to experts in business and management, as evidenced by the average citation number of 27,84, which is particularly high for the academic sector.

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Table 1. Main documents

Description	Results
Main data information	
Time span	2000-2023
Sources	45
Documents	129
Annual growth rate	10.53%
Average time since publication (in years)	5.39
Average citations per document	27.84
Document content	
Plus keywords (id)	990
Author's keywords (de)	527
Authors	
Number of authors	456
Number of documents by single author	12
Author collaboration	
Average number of authors per document	3.73
International co-authors	41.09

Source: Author's elaboration through Biblioshiny

3.1 Sources and Documents.

From 2015, the number of publications increased rapidly, showing an interest that remains high in the following years (Figure 2). As can be seen from Table 2, the leading journal by a large margin among the most relevant sources is the Journal of Cleaner Production. This international journal has a transdisciplinary character and aims to publish on environmental and sustainability topics. Specifically, "Cleaner Production" aims to prevent waste production by increasing the efficiency of energy, water, resources, and human capital.

Table 3 depicts the main documents extracted from the sample. The first paper, in terms of number of citations, addresses the topic of prefabrication technology promoted by the Chinese government to enhance the quality and productivity of constructions. This topic was assessed in an environmental study (Cao et al., 2015). The results reveal that prefabrication is more energy-efficient and reduces environmental damage compared to traditional on-site construction.

The second research in terms of number of citations is the study of Wu & Sun (2018), In which it is confirmed that the optimization of energy use in operational management must consider when to turn machines on or off and the speed of execution. In particular, the authors suggest a model for flexible factory planning, calculating energy consumption and developing a genetic algorithm for optimizing timings, consumption, and machine start-ups and shutdowns.

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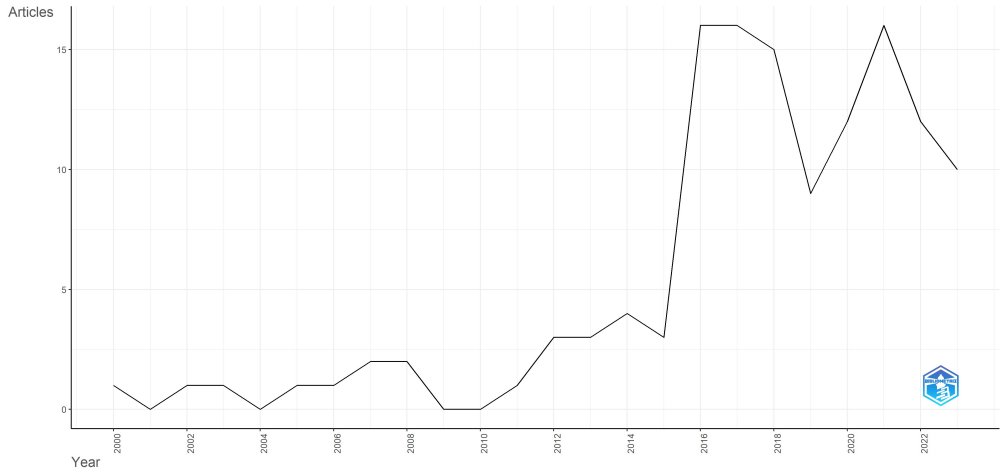
Figure 2. Annual scientific production



Source: Author's elaboration through Biblioshiny

Table 2. Most relevant sources

Sources	Papers
Journal of Cleaner Production	65
International Journal of Construction Management	6
Construction Management and Economics	4
Engineering, Construction and Architectural Management	4
Cities	3
Journal Of Construction Engineering and Management	3
Computer Law and Security Review	2
International Journal of Technological Learning, Innovation and Development	2
Research In Transportation Business and Management	2
Research Policy	2

Source: Author's elaboration through Biblioshiny

The third paper in the table deals with the supply chain and the fundamental integration in order to improve the performance of construction projects. The study of Mesa et al. (2016) uses the general performance model to assess how project delivery systems influence relationships in the supply chain and project performance, finding that communication, alignment of interests, teamwork, trust, and benefit sharing are key factors.

The fourth document is among the less recent and studies life cycle assessments used to evaluate the environmental impacts of products and processes. In the construction sector, the study of Treloar et al. (2000) suggests a hybrid method that integrates traditional life cycle assessment data with input-output data, improving the overall completeness and reliability of environmental assessments.

Among other documents, the study of Schnitzer et al. (2007) that suggests the promising technical and economic feasibility of using thermal solar energy in industrial processes, contributing to a zero-emission sustainable industry. In addition to the previous research, of great relevance is the literature analysis of Hossain & Ng (2018) which examines the application of life cycle analysis to construction, highlighting gaps in considering the concept of circular economy and proposing a comprehensive framework to improve the sustainability of the construction sector.

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Table 3. Most relevant documents

Paper	Number of citations	Average citation per year
Cao, X., Li, X., Zhu, Y., & Zhang, Z. (2015). A comparative study of environmental performance between prefabricated and traditional residential buildings in China. In *Journal of Cleaner Production* (Vol. 109, pp. 131–143). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2015.04.120	222	24,67
Wu, X., & Sun, Y. (2018). A green scheduling algorithm for flexible job shop with energy-saving measures. In *Journal of Cleaner Production* (Vol. 172, pp. 3249–3264). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2017.10.342	164	27,33
Mesa, H. A., Molenaar, K. R., & Alarcón, L. F. (2016). Exploring performance of the integrated project delivery process on complex building projects. In *International Journal of Project Management* (Vol. 34, Issue 7, pp. 1089–1101). Elsevier Ltd. https://doi.org/10.1016/j.ijproman.2016.05.007	129	16,13
Treloar, G. J., Love, P. E. D., Faniran, O. O., & Iyer-Raniga, U. (2000). A hybrid life cycle assessment method for construction. In *Construction Management and Economics* (Vol. 18, Issue 1, pp. 5–9). Routledge Journals. https://doi.org/10.1080/014461900370898	120	5,00
Schnitzer, H., Brunner, C., & Gwehenberger, G. (2007). Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes. In *Journal of Cleaner Production* (Vol. 15, Issues 13–14, pp. 1271–1286). https://doi.org/10.1016/j.jclepro.2006.07.023	118	6,94
Chang, R. D., Soebarto, V., Zhao, Z.-Y., & Zillante, G. (2016). Facilitating the transition to sustainable construction: China's policies. In *Journal of Cleaner Production* (Vol. 131, pp. 534–544). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2016.04.147	102	12,75
Hossain, Md. U., & Ng, S. T. (2018). Critical consideration of buildings' environmental impact assessment towards adoption of circular economy: An analytical review. In *Journal of Cleaner Production* (Vol. 205, pp. 763–780). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2018.09.120	99	16,50
Ding, Z., Wang, Y., & Zou, P. X. W. (2016). An agent based environmental impact assessment of building demolition waste management: Conventional versus green management. In *Journal of Cleaner Production* (Vol. 133, pp. 1136–1153). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2016.06.054	95	11,88
Cheng, B., Lu, K., Li, J., Chen, H., Luo, X., & Shafique, M. (2022). Comprehensive assessment of embodied environmental impacts of buildings using normalized environmental impact factors. In *Journal of Cleaner Production* (Vol. 334). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2021.130083	87	43,50
Foo, K. Y. (2013). A vision on the role of environmental higher education contributing to the sustainable development in Malaysia. In *Journal of Cleaner Production* (Vol. 61, pp. 6–12). https://doi.org/10.1016/j.jclepro.2013.05.014	84	7,64

Source: Author's elaboration through Biblioshiny

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3.2 Thematic analysis

The following section explores the main themes through different analyses based on the authors' keywords or the most significant keywords by frequency of appearance.

The main words emerging from the keyword analysis, visible in Figure 3, are "life cycle" (58) and "environmental impact" (49). Authors use the first term to identify studies related to the in-depth examination of the life cycle of products and how this can represent an advantage for the circularity of the economy in various sectors such as: transport (Cristiano, 2022), specialized studies of the industrial sector (Lo Giudice et al., 2017), insights for the recovery of natural resources (Ghimire et al., 2017; Long et al., 2023). The latter is used in studies that consider the environmental impact crucial in predisposition starting from the spatial dimension (Diez-Rodríguez et al., 2019) and the environmental impact of industrial buildings (Harelimana et al., 2020).

Among the other words, "sustainable development" (30) and "decision making" (23) stand out. The topic of sustainable development seems to be among the most significant when describing the phenomenon of building impact assessment. In particular, some articles address the transition from traditional construction systems to ecological systems (Chang et al., 2016). Moreover, other authors have focused on the integration of disruptive technologies and the power of artificial intelligence in building construction (Hamida et al., 2021). The discussion of decision-making is essential to change current construction paradigms and promote an impact assessment that can determine the optimal parameters of dwellings (Sohn et al., 2017), or regarding the study of costs and prices (Teo et al., 2022).

Figure 3. Significant keywords distributed in a word cloud

Source: Author's elaboration through Biblioshiny

Figure 4 shows trending topics, displaying the main themes over the years. Until 2016, the authors' interest was mainly in environmental impact assessment. In particular, the studies focus on studying the erosion of natural resources related to property construction (Bolin & Smith, 2011; Burge, 2008). From 2016 onwards, the interest shifted towards energy efficiency and the new effective forms of environmentally conscious property construction (Hird & Pfotenhauer, 2017). In recent years, attention has expanded to the life cycle of elements and recycling and the life cycle impact assessment in the context of the circular economy (Tran et al., 2023).

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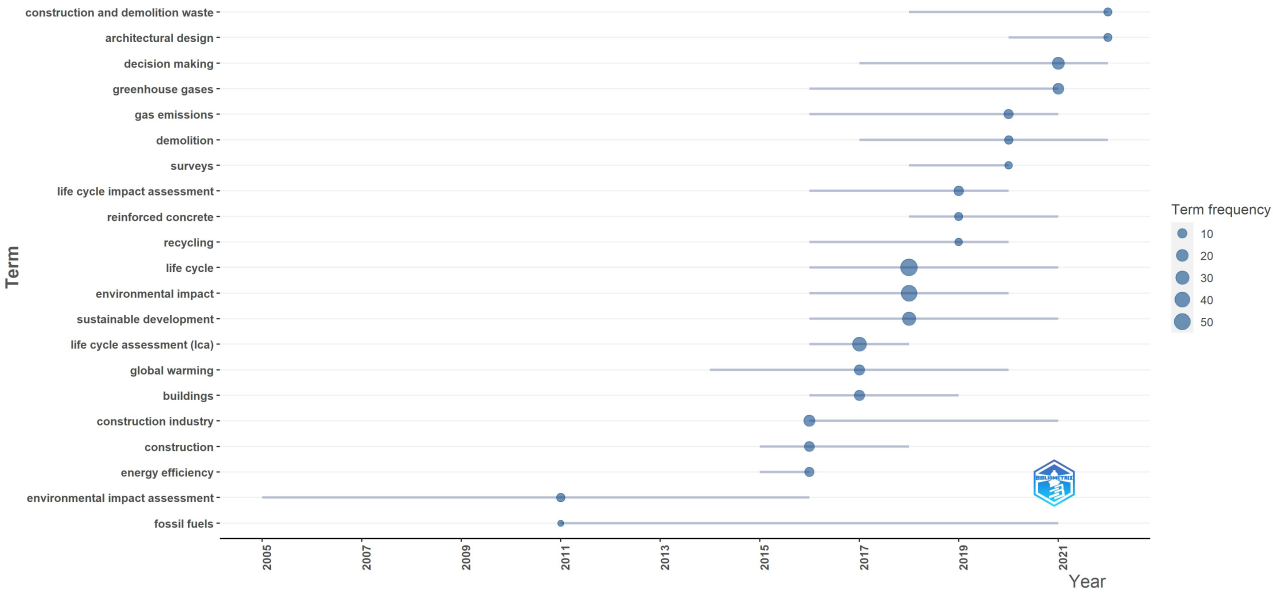
Figure 4. Trending Topics



Source: Author's elaboration through Biblioshiny

Figure 5 shows the results of the connections established by the VosViewer software (Van Eck & Waltman, 2011), highlighting two main clusters developed based on the economic context of application. From an economic standpoint, it is clear that growth, sustainability, and balance have a strong correlation, especially environmental sustainability and economic aspects require investments that can lead to balance considering sustainable materials provided there is little global market competition when considering these aspects not impacting collective well-being (Gajbiye, 2018). European and national markets and regulations condition strategies and costs associated with construction; if regulations and adopted policies increase the required criteria, market economies look for the lowest price with a balance to be achieved (Bon & Hutchinson, 2000). To this end, processes, materials, and impact require careful analysis to determine the variables at play. In most cases, the reuse of buildings for other purposes and redesign do not require cheaper solutions but solutions that take into account environmental impacts or other contextual factors (Laefer & Manke, 2008).

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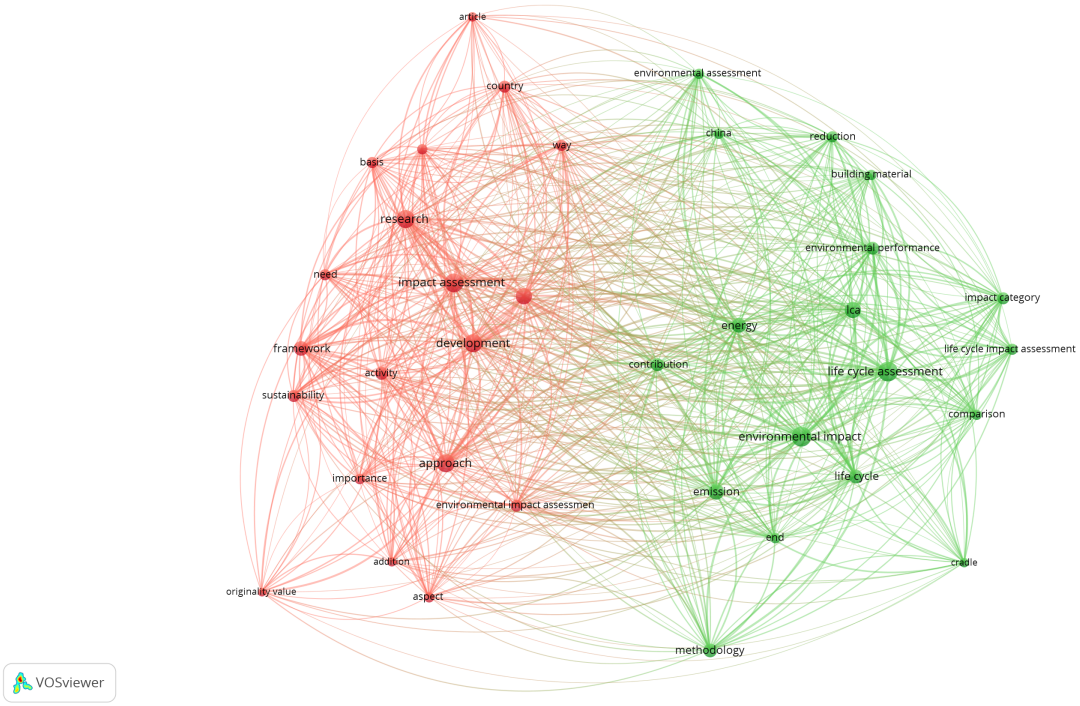
Figure 5. Thematic analysis of content



Source: Author's elaboration through VosViewer

The first significant cluster concerns the Life Cycle Assessment (LCA) based on the impact definition generated by materials and energy consumption. The approach is based on both the use of recycled materials and guaranteed energy savings for the building and the use of new, less energy-impactful technologies (Ingrao et al., 2016). Some studies associate the LCA with the Construction Environmental Performance Assessment System (CEPAS) as in Figure 6, a holistic assessment tool for various types of buildings with a clear boundary of the entire building's life cycle, covering the pre-design, design, construction, and demolition stages and operation based on indicators that include environmental, social, and economic aspects (Cao et al., 2015).

The study by Cao et al. (2015) also associates the LCA with the Building Health Impact Assessment System (BHIAS) by integrating several indicators provided in the evaluation approach. Figure 7 shows the aspects considered and the variables mapped. Using technologies in this case also impacts the results that can be achieved, on material selection, and on determining the components to use, also impacting health and consequent energy consumption following building construction.

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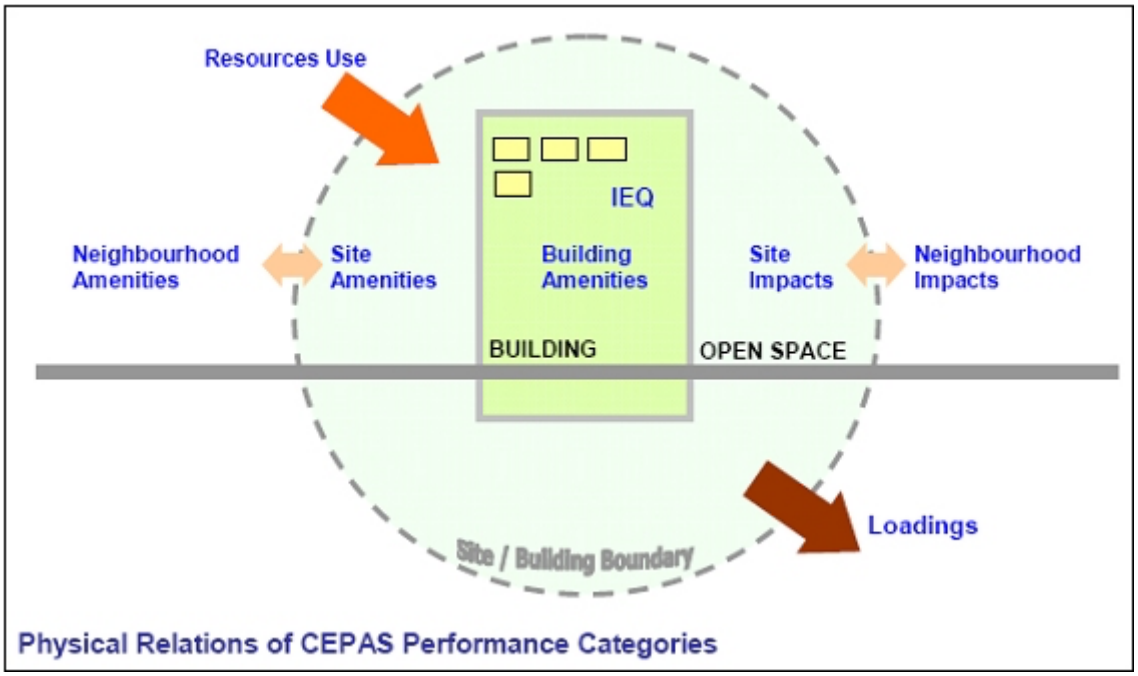
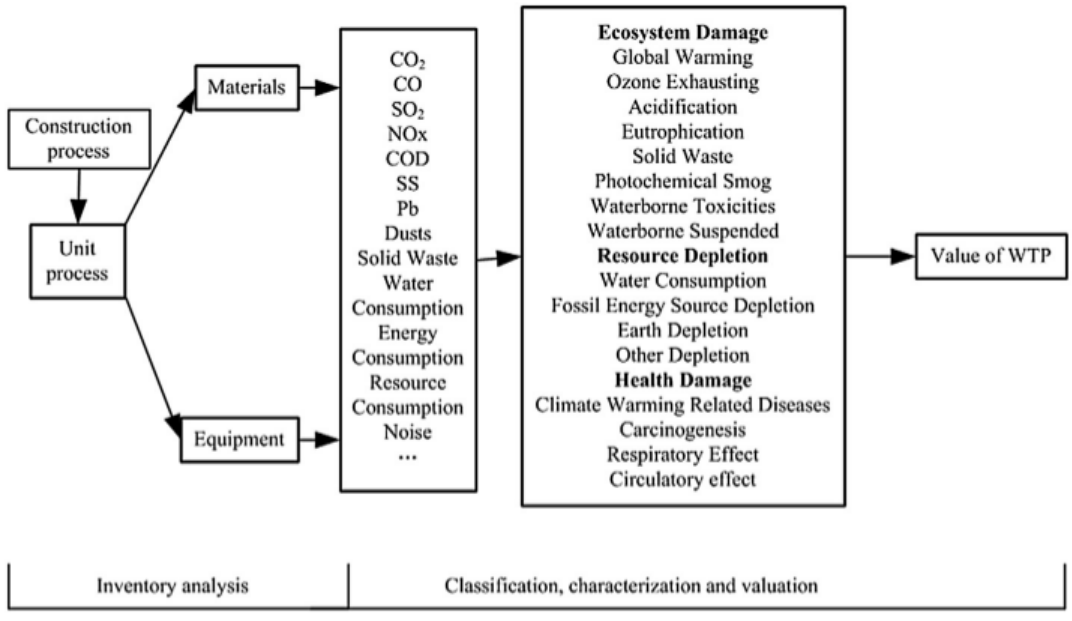
Figure 6. Conceptual map



Source: Adapted from (CEPAS Application Guidelines, 2006)

Figure 7. Summary table



Source: CEPAS e BHIAS based on Cao et al., 2015.

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Since the LCA the transformation process from input to output is essential for an effective assessment, there are also corrective measures that improve the assessment of only some elements, omitting others that could distort the achieved result (Treloar et al., 2000). Specifically, it is suggested to select the best available LCA input±output models and differentiate the application of the hybrid LCA method proposed by Treloar et al. (2000) on different types of buildings and other non-building products. The articles discussing LCA often associate the Environmental Impact with material use and the life cycle described and outlined through the Sankey diagram (Ismaeel & Lotfy, 2023). The impact is also associated with emissions and measurable energy consumption through cumulative energy demand (CED), ReCiPe, greenhouse gas (GHG) emission rate, and the energy payback time (EPBT) (Hadi & Heidari, 2021; Sandanayake et al., 2017) with a possible impact on health (Sandanayake et al., 2022). The impacts associated with the use of construction materials and health are usually classified based on climate change, air pollution, photochemical oxidant formation, and water consumption (Shi et al., 2022). Additionally, constructions, demolitions, and renovations generate waste (bricks for masonry, permeable bricks, and thermal insulation blocks) often toxic that can cause freshwater ecotoxicity, marine ecotoxicity, carcinogenic toxicity, and non-carcinogenic toxicity to humans; such toxicities can be reduced if a product recycling process is applied, which, according to studies, also has an impact on CO2 emissions reduced by 15.6kg per functional unit (Qiao et al., 2022). Also, the use of biocomponents like bio-renewable content (BRC) formulation for wooden floor coatings can reduce the impacts generated by smog formation, acidification, eutrophication, and respiratory effects by 30% (Montazeri & Eckelman, 2018).

Other impacts to be mapped concern energy, requiring particular attention to reducing greenhouse gas (GHG) emissions by between 20% and 30% compared to each building's emissions according to European Union requirements with a target set at 20% (Biancone et al., 2021; Brescia et al., 2023; Gottsche et al., 2016). The relationship between the structured aspects of buildings, energy impact, and economic assessment is present in the Environmental Impacts Cost Assessment Model (EICAM) that, in design phases, allows defining energy cost, operational energy carbon, carbon embodied in the envelope, and total carbon emissions (Hamida et al., 2021).

The impact assessment associated with the previous clusters uses different methods, although the LCA is predominant and includes various variables. Among the other methods considered, the Data Envelopment Analysis (DEA) determines in the reconstruction of external walls which inputs provide the best outputs in terms of efficiency by testing 175 different types (Iribarren et al., 2015). The use of the USEPA TRACI 2.1 impact assessment method is particularly significant when discussing biological or chemical-derived materials used for construction with environmental impact (Montazeri & Eckelman, 2018). Only in the demolition phase, even partial, is the agent-based modeling (ABM) approach used, highlighting how direct management of demolition works by engineers or architects reduces pollution and the generated environmental impact by 50% (Ding et al., 2016). Among the adopted frameworks associated with the approach, there is also the Building Information Modelling (BIM), which, in defining six impact-related dimensions, uses specific verification and quality control procedures that allow engineers to reduce the environmental impact (Ismaeel & Lotfy, 2023).

The different approaches and renovation phases are always associated with measurable sustainability criteria through the adoption of circular economy approaches (Hossain & Ng, 2018), energy use and related emissions (Hadi & Heidari, 2021), used renewable energy (Passerini et al., 2017), elements based on the Green-Star certification widespread in other countries e.g. Australia (https://new.gbca.org.au/green-star/rating-system/design-and-built/) (Tran et al., 2023), the materials and potentially toxic substances for humans used based on the requirements of the Global Sustainability Agenda (Kirchhübel & Fantke, 2019).

The creation or use of independent committees or agencies allows for reducing geopolitical risks in decisions regarding the destination and using materials that influence the impact, mitigating the financial risks associated with imposed choices (Sheetal et al., 2023).

3.3 Geographical Analysis

This section analyses the adopting nations and countries based on the number of publications. Figure 8 shows that the most prolific nation is China, with 53 publications. The impact assessment of constructions is essential to the decision-making process for large-scale construction projects (Shi et al., 2022). China has a growing concern for the environment and is looking to improve the sustainability of its constructions to promote more sustainable construction practices through the adoption of eco-friendly technologies and energy efficiency standards as found in the “The Belt and Road” Project (Schulhof et al., 2022).

Research conducted in the United States follows, with 26 from this sample. The environmental impact assessment is a mandatory process for building projects that involve government funding or approvals. Although regulations vary from state to state, environmental impact assessment includes analyzing the environmental, social, and economic effects of the project (Bolin & Smith, 2011). Italian publications number 24 and focus on construction management that can have a significant impact

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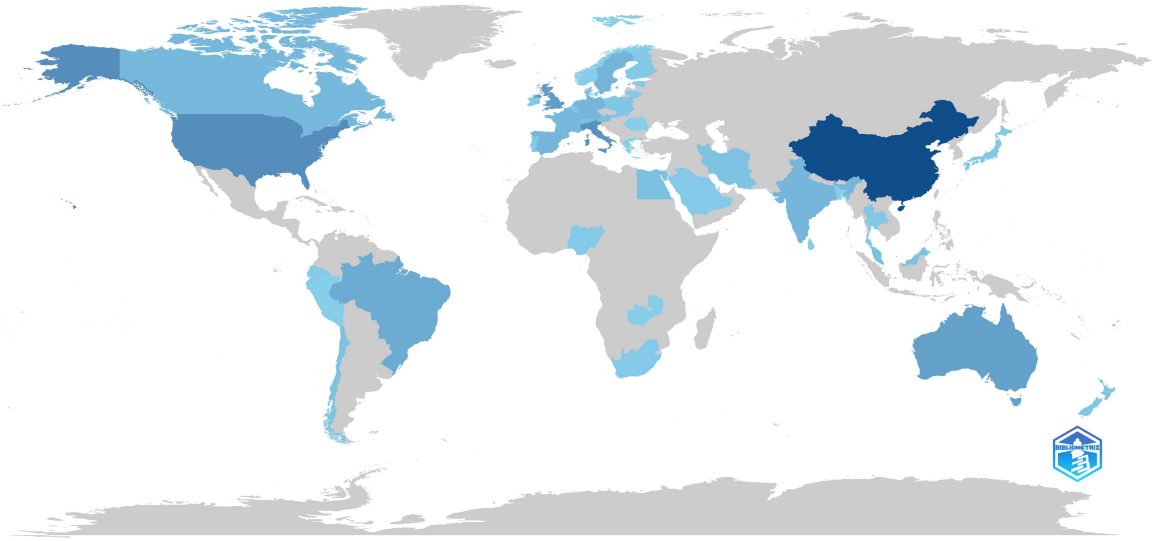
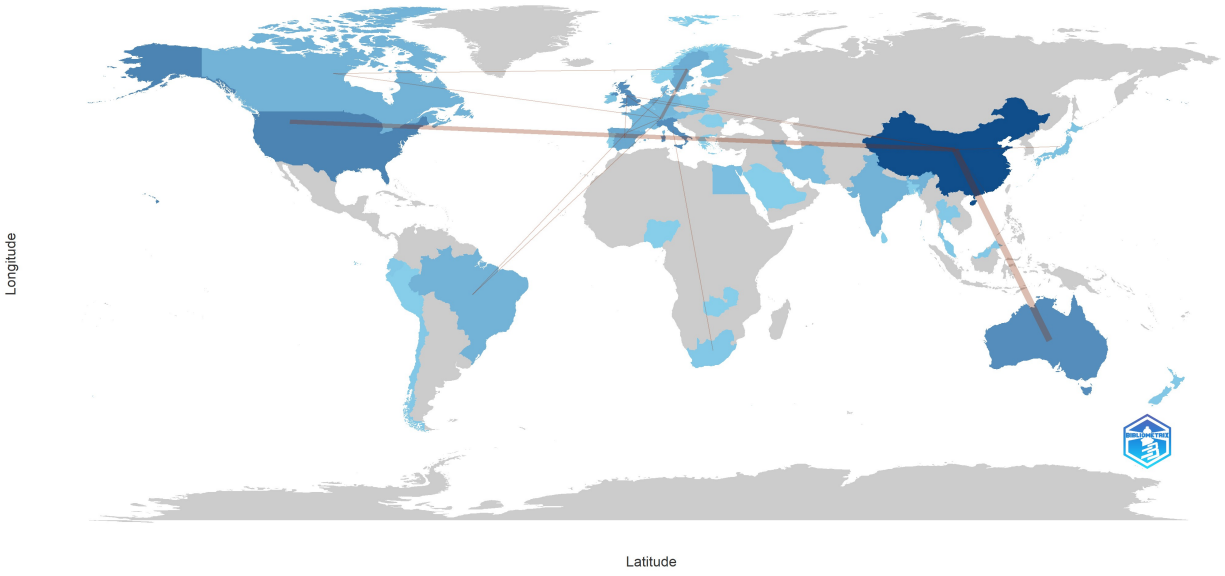
on the environment, such as air quality, resource consumption, landscape, traffic, and much more (Cristiano, 2022; Vitale et al., 2018). Finally, publications from the United Kingdom number 20 explore impact assessment considering effects like land use, transportation, noise, and the surrounding ecosystem (Rossi et al., 2017).

Figure 8. Scientific output of different countries.



Source: Author's elaboration through Biblioshiny

Figure 9. Map of strategic collaborations between countries.



Source: Author's elaboration through Biblioshiny

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Built based on the previous image, Figure 9 highlights the relationships between the authors from individual countries. The most significant relationship concerns the co-authorship of seven documents between China and Australia. One reason is related to the high rate of collaboration between different building projects, especially in the field of infrastructure and natural resources. Impact assessments of constructions are a critical aspect of this collaboration, as both countries seek to ensure that projects are conducted in a sustainable and environmentally friendly manner (Tran et al., 2023). Moreover, the relationship between the USA and China with 4 papers appears particularly significant. The reasons underlying the intensity of collaboration between the countries are the desire to ensure that projects comply with environmental regulations and have a sustainable impact (Huang et al., 2018). Lastly, the collaboration between Switzerland and Sweden is highlighted. At the heart of this collaboration is a strong shared commitment to sustainability and environmental awareness.

4. Discussion and conclusion

Although essential for the global economy, construction has significant impacts on the environment and society (Díaz-López et al., 2021). Building impact assessment has become crucial to balance economic, environmental, and social sustainability (Ameen et al., 2015). In recent years, increasing awareness of environmental and urban challenges has led to a greater focus on how construction projects affect the surrounding world (Zahra & Wright, 2016).

This study represents a step forward in understanding building impact assessment through a bibliometric analysis (Lanzalonga et al., 2023; Sadraei et al., 2022). Moreover, the article emphasizes the importance of considering economic, environmental, and social aspects in the building impact assessment, considering the United Nations' 2030 agenda goals for sustainable cities (United Nations, 2015). Ultimately, this study represents a step forward in promoting sustainability in construction by better understanding its dynamics and challenges.

To address the initial RQ1, three distinct angles are considered: (i) publication sources and document types, (ii) analysis of themes, and (iii) examination of geographical trends. In terms of publication sources and document types, the research notes a rise in scholarly articles related to building impact assessment from 2015 onwards, indicating an escalating interest in this area. The "Journal of Cleaner Production" stands out as a leading publication in this domain, primarily focusing on environmental sustainability and topics like waste reduction and resource efficiency (Díaz-López et al., 2021). Among the most referenced studies, a research from China underscores the benefits of prefabrication technology in enhancing the quality and productivity of construction, with a particular emphasis on environmental factors (Cao et al., 2015). Additionally, a study focused on improving energy efficiency in building operations using modeling and genetic algorithms (Wu & Sun, 2018). The aspect of supply chain management was explored in another research, analyzing its impact on the performance of construction projects, with a special focus on elements such as communication and trust (Mesa et al., 2016).

Regarding thematic analysis, the most relevant keywords in publications include "life cycle", "environmental impact", "sustainable development", and "decision making". Over the years, the focus has shifted from analyzing environmental impact to energy efficiency and a circular approach. Keyword connection analysis highlighted thematic clusters related to life cycle analysis, sustainable material use, and environmental impact evaluations. Geographically, China has published the most articles on the subject, followed by the United States, Italy, and the United Kingdom. The most significant country relationships include collaborations between China and Australia, China, and the USA, as well as Switzerland and Sweden, all focused on the common goal of ensuring sustainability in construction projects and compliance with environmental regulations.

In addressing RQ2, the research uncovers a reverse correlation between the costs of building renovations and their sustainability, affecting both environmental and public health outcomes. Essentially, the greater the sustainability and adherence to standards, the more substantial the financial outlay required during the construction or renovation stages (Bon & Hutchinson, 2000; Gajbiye, 2018). This inverse relation necessitates finding a middle ground between the required demands/needs and the expenses incurred, or alternatively, seeking policy recognition for meeting specific environmental benchmarks. Key among these criteria is the adoption of a uniform measurement methodology. The study points out that Life Cycle Assessment (LCA) emerges as the most effective framework for evaluating the pre-design, design, construction, demolition, and operation phases, using indicators that encompass environmental, social, and economic aspects (Cao et al., 2015). This method can be supplemented with secondary techniques to ascertain the most impactful components (DEA analysis), especially when materials and components are pre-identified and catalogued; the USEPA TRACI 2.1 assessment tool is useful for assessing the impact of biological materials used, and Building Information Modeling (BIM) proves valuable in analyzing engineering process repercussions (Ding et al., 2016; Iribarren et al., 2015; Ismaeel & Lotfy, 2023; Montazeri & Eckelman, 2018). The fundamental principle of Life Cycle Assessment, which is the relationship between inputs and outputs, serves as a foundation for these methodologies.

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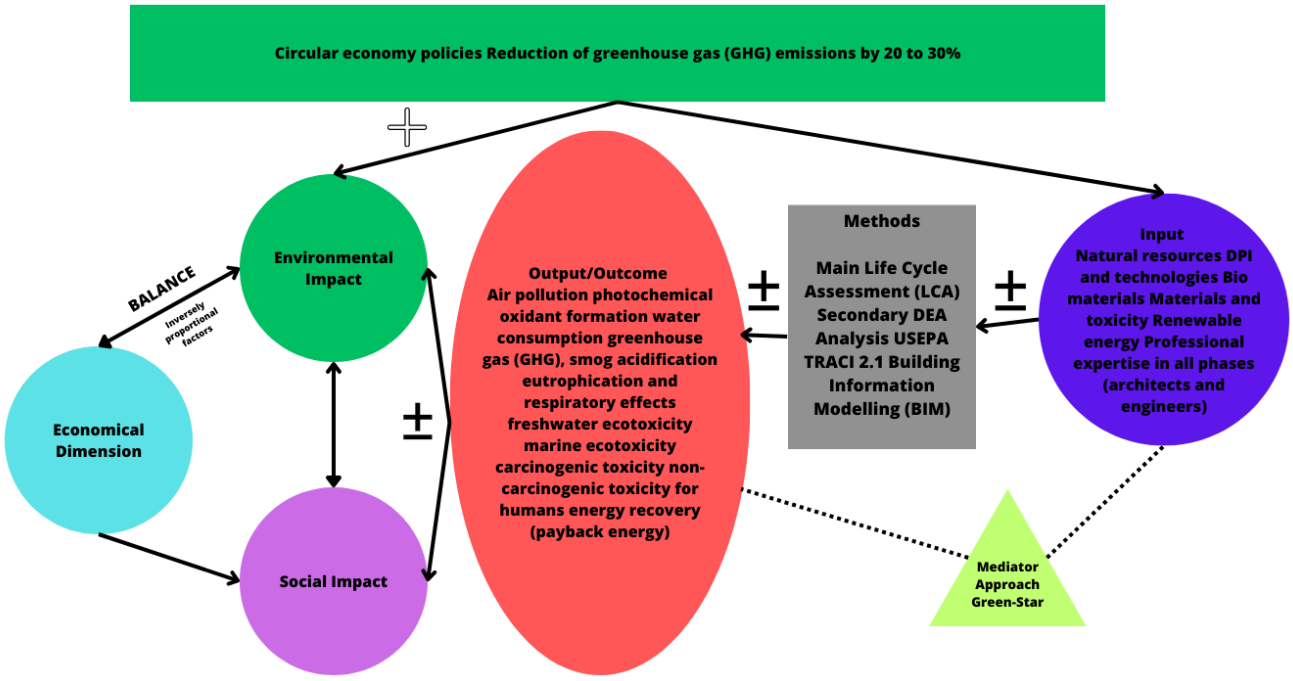
For this purpose, the considered inputs must include human raw material toxicity, natural resource consumption, used protection devices and technologies, bio materials used, renewable energies, professional skills (architects and engineers) even during demolition phases to reduce impacts, and allocated economic resources (Cao et al., 2015; Hadi & Heidari, 2021; Hossain & Ng, 2018; Kirchhübel & Fantke, 2019; Montazeri & Eckelman, 2018; Passerini et al., 2017; Treloar et al., 2000). Outputs with a direct impact on the environment include climate change, air pollution, photochemical oxidant formation, water consumption, greenhouse gas (GHG), smog, acidification, eutrophication, and respiratory effects, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity and non-carcinogenic toxicity, and possible energy recovery (payback energy) (Hadi & Heidari, 2021; Montazeri & Eckelman, 2018; Qiao et al., 2022; Shi et al., 2022). The use of Green-Star-certified elements generates positive outcomes in the renovation process.

Both for inputs and outputs, European policies guide operations by highlighting rewards for the macro context in terms of health and environmental fallout and, at the same time, a recovery for the energy cost in the medium term; these policies concern circular economy approaches and respect for the reduction of 20% of CO2 emitted by heating and electrical plants, possibly oriented to 30% (Biancone et al., 2021; Brescia et al., 2023; Gottsche et al., 2016; Hossain & Ng, 2018). The presence of committees or autonomous agencies guarantees sustainability and the processes implemented (Sheetal et al., 2023). The different highlighted elements constitute rewarding (+) or penalizing (-) factors in evaluating all building use phases and can be summarized in Figure 10. The study also highlights that except for health-related social impacts, there are not many studies providing a weight on the fallout and role of a building, even though the role of the context in which it is located is mentioned (Laefer & Manke, 2008).

Figure 10. Key Elements in Building Impact Assessment



Source: Authors' elaboration

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4.1 Limitation and future research

Like all studies, this article also has its limitations. Firstly, using only the Scopus database might limit the sample of selected articles. Therefore, we cannot rule out any adverse scientific contributions not included in our study. Secondly, the thematic analysis carried out, although done independently by the researchers, could have elements of subjectivity in its investigation. Lastly, using keywords could limit the scope of the research conducted so far. Further advancements in the field could stem from our limitations. Therefore, future research could be undertaken using other databases, such as the Web of Science and various research sources. Moreover, thematic analysis techniques could be refined favoring the selected sample using specific research software capable of outlining the sentiments and variables of managers on the issue of building impact assessment. Additionally, research initiatives based on single or multiple cases could be conducted to explore ongoing virtuous initiatives.

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