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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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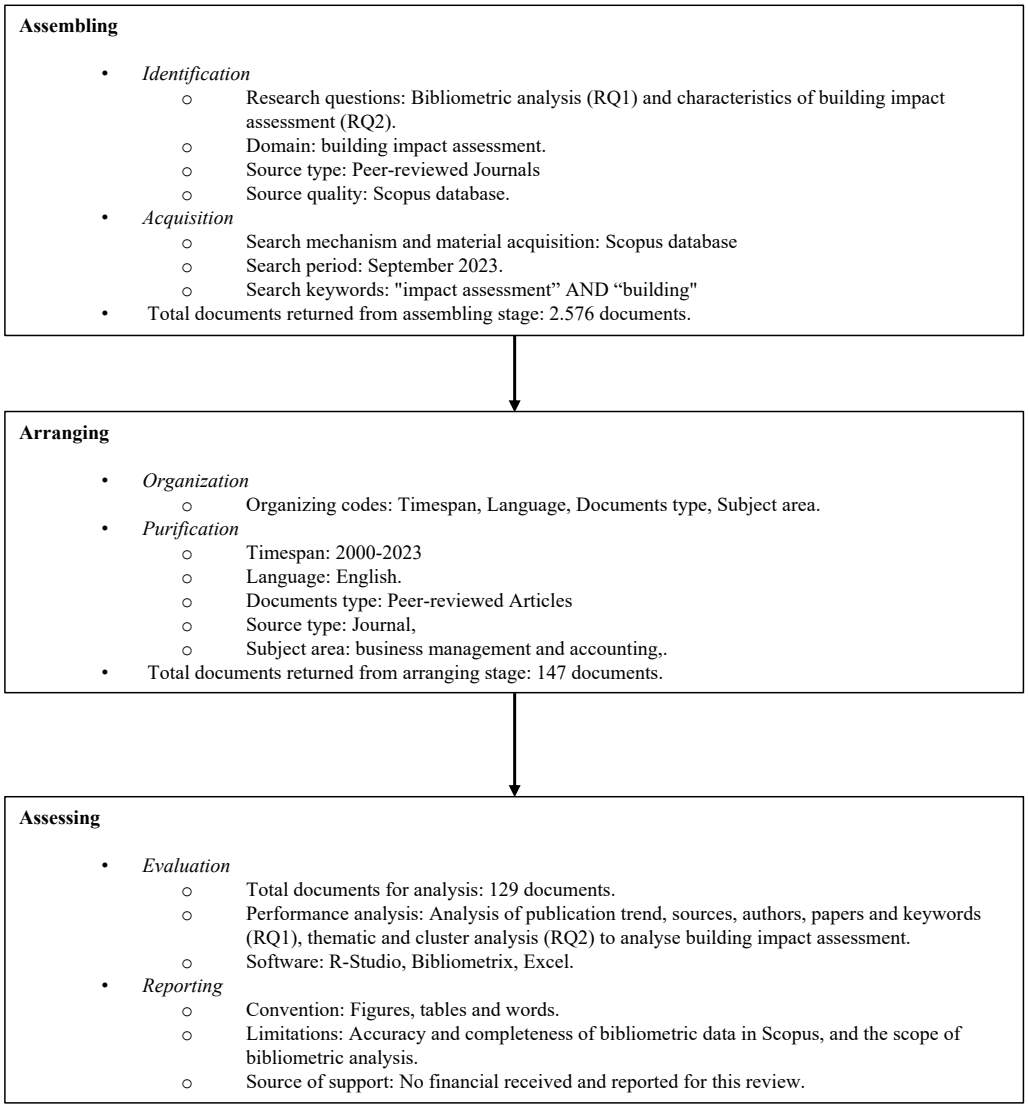
Figure 1. Data collection methodology



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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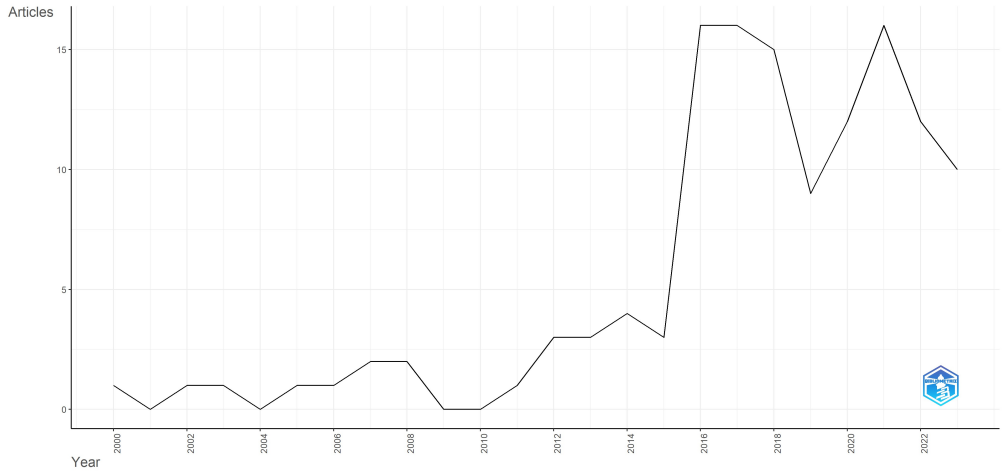
Figure 2. Annual scientific production



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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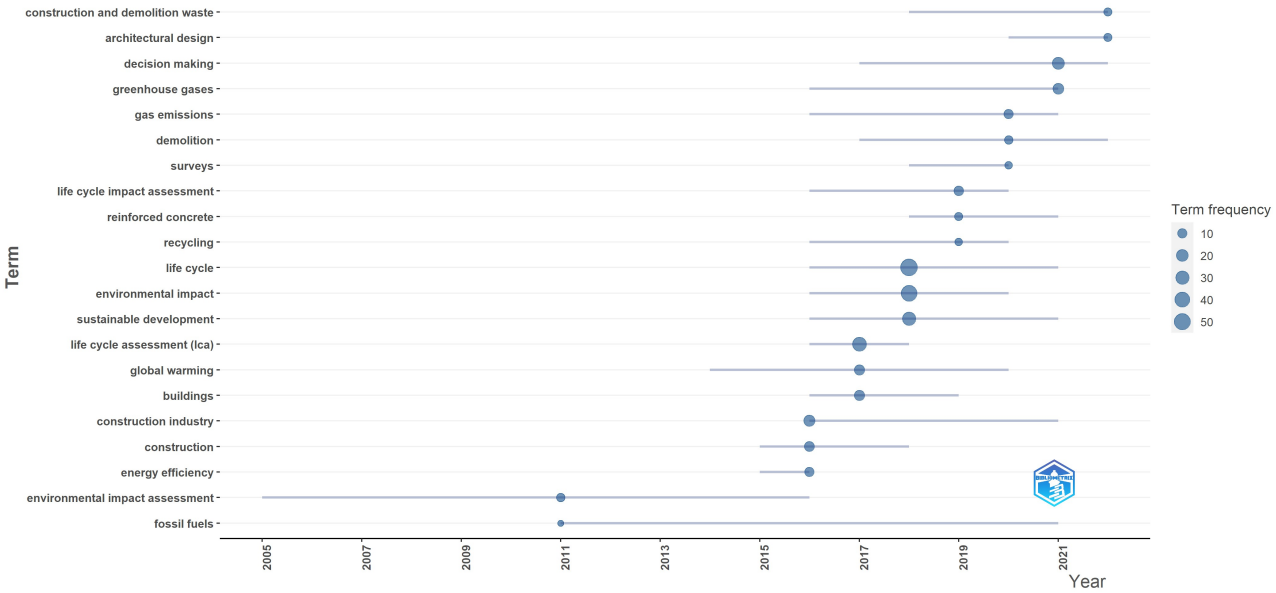
European Journal of Social Impact and Circular Economy

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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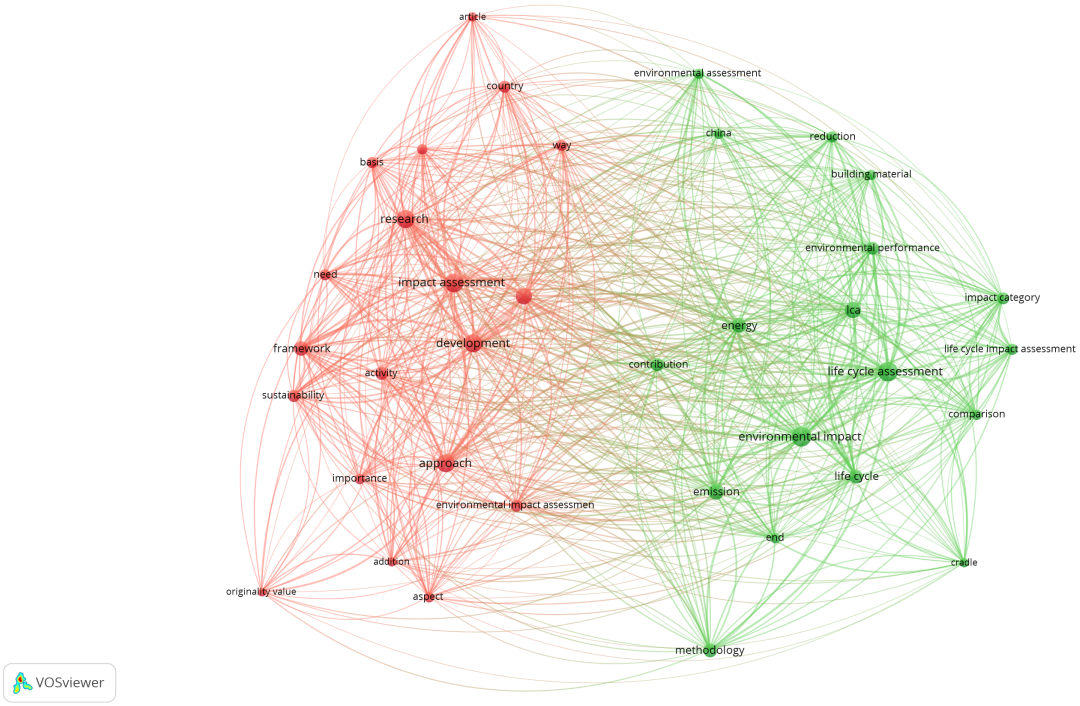
Figure 5. Thematic analysis of content



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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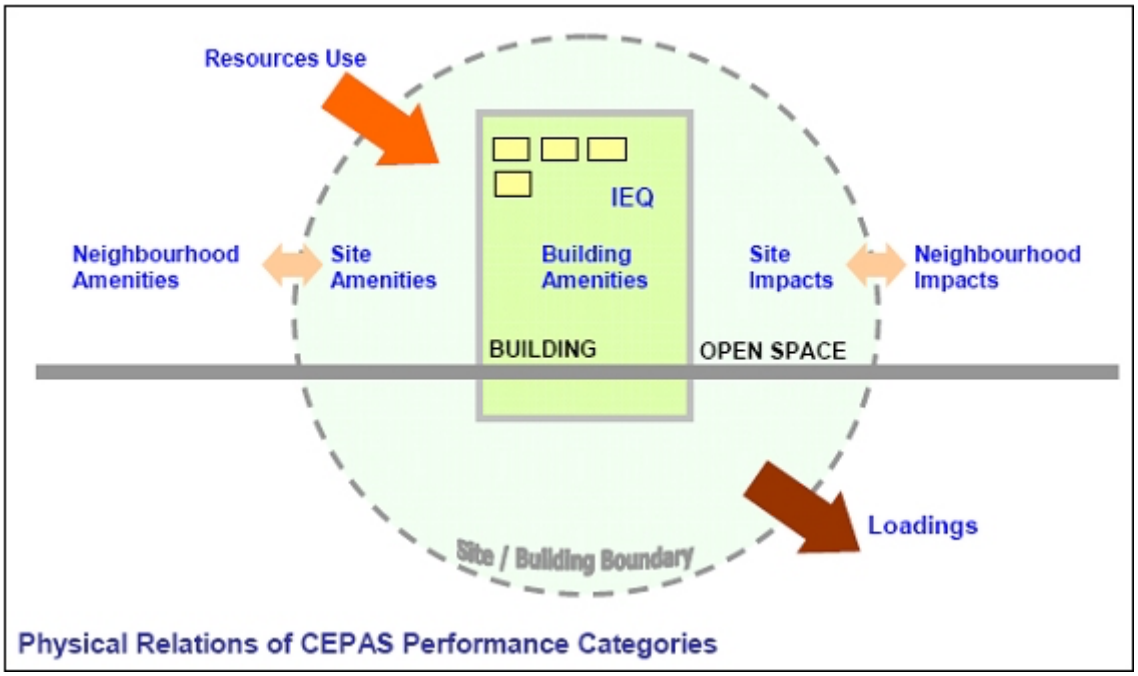
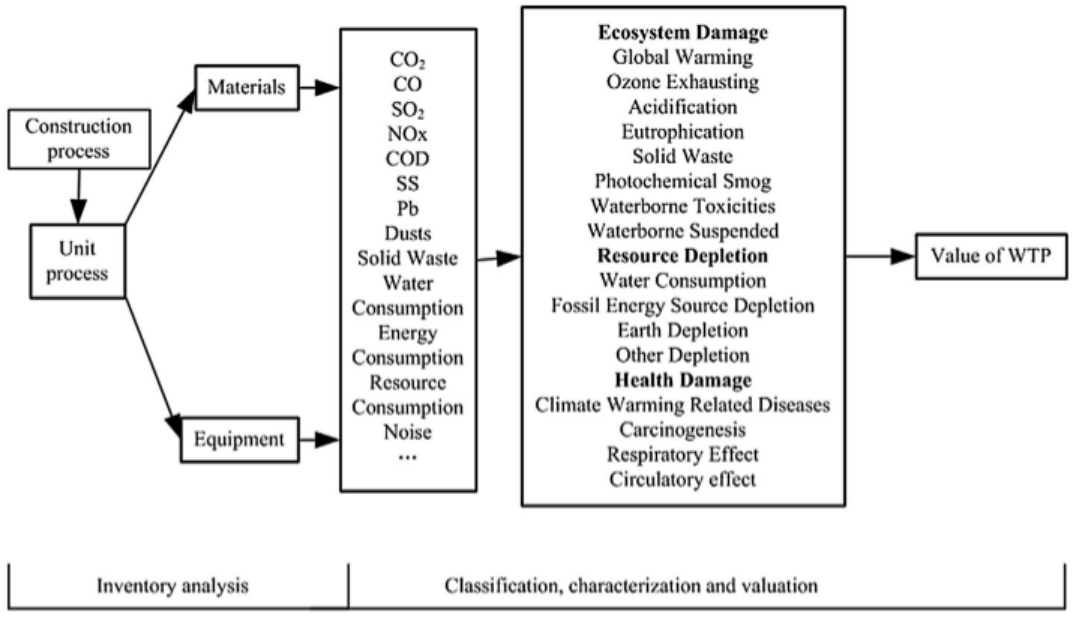
Figure 6. Conceptual map



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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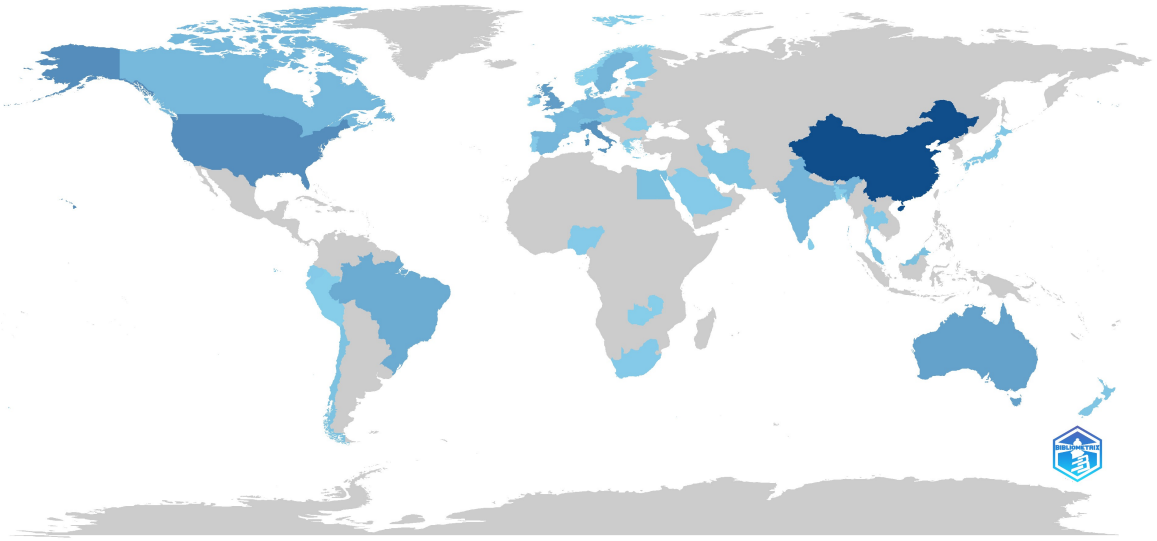
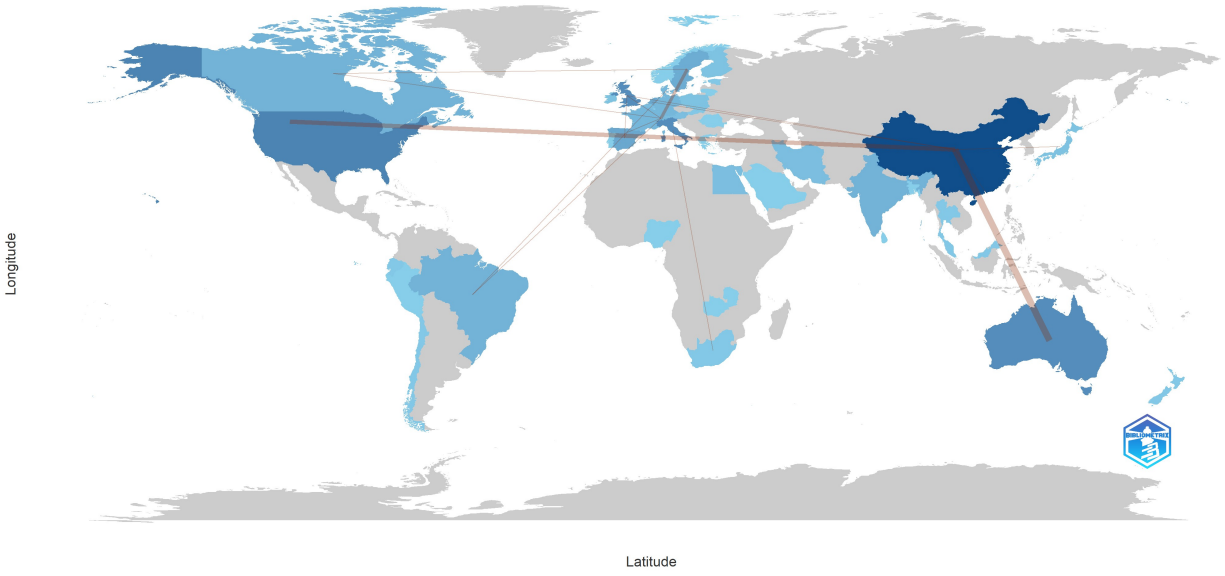
on the environment, such as air quality, resource consumption, landscape, traffic, and much more (Cristiano, 2022; Vitale et al., 2018). Finally, publications from the United Kingdom number 20 explore impact assessment considering effects like land use, transportation, noise, and the surrounding ecosystem (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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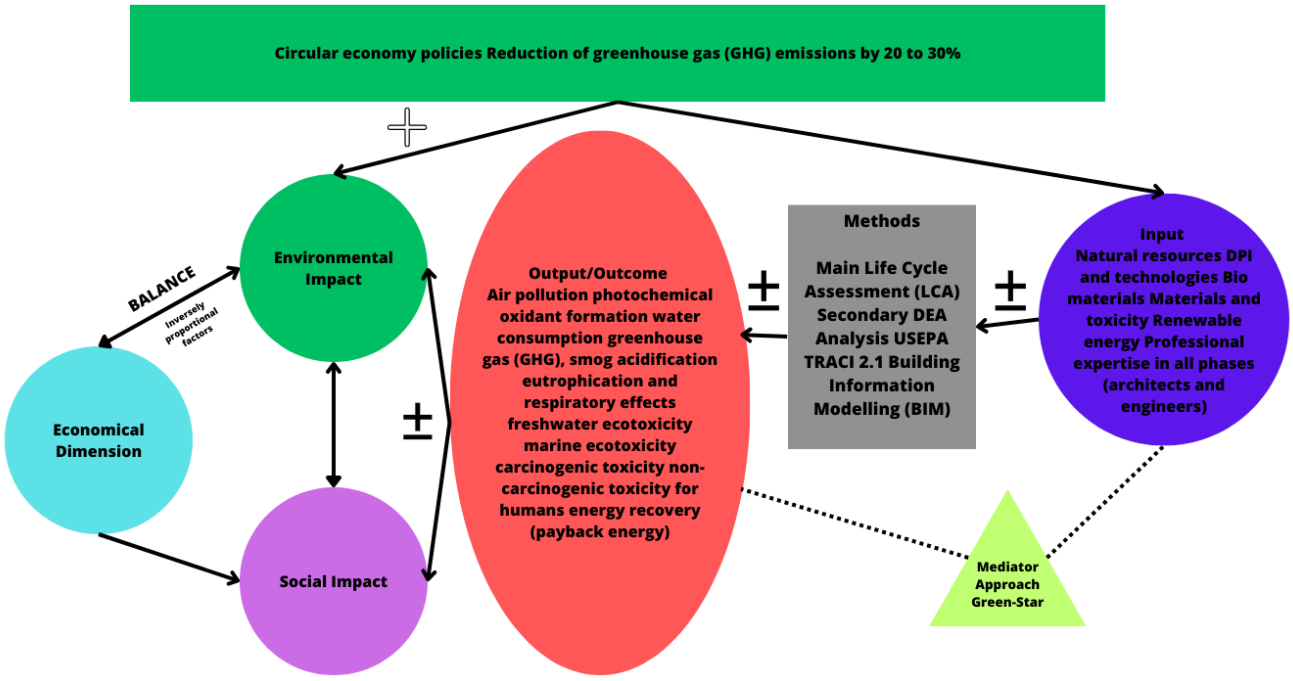
For this purpose, the considered inputs must include human raw material toxicity, natural resource consumption, used protection devices and technologies, bio materials used, renewable energies, professional skills (architects and engineers) even during demolition phases to reduce impacts, and allocated 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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