buildings

Review

Life Cycle Assessment and Circular Building Design in South Asian Countries: A Review of the Current State of the Art and Research Potentials

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Abstract: A literature survey was proposed, aiming at summarizing the state of the art and, consequently, the research potential, in the increasingly popular field of circular economy, specifically applied to the construction industry in South Asian countries (Pakistan, India, and Bangladesh). In particular, the role of a life cycle assessment (LCA) to support the circular building design concept in construction projects was investigated. This review organized 71 published papers that examined environmental building assessments, certifications for sustainable buildings, the awareness of sustainable buildings, and recent advancements in this field between 2005 and 2022. The review pointed out that half of the LCA studies used the cradle-to-grave LCA methodology for environmental impact assessment, while the other half used the cradle-to-cradle LCA methodology. Regardless of the recent research, the literature still lacks the cradle-to-cradle implementation of the LCA methodology in selected countries which is essential for implementing truly circular building strategies. Moreover, the literature showed a lack of interest and awareness among all stakeholders in the construction of environmentally friendly buildings. The main barrier to carry out LCA for building performance is the unavailability of a regional database, which was pointed out in the literature, as well as the criteria for certification that are not available or do not comply with the standards of the specific contexts of Pakistan, India, and Bangladesh.

Keywords: life cycle assessment; circularity; circular economy; circular building design; building materials; building assessment; sustainable design awareness

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1. Introduction

In the past decade, there has been a sharp growth in construction activity worldwide due to the need for better infrastructure and a better standard of living. From the design stage to the demolition stage, the building industry is faced with several complications. Negative environmental effects are one of the main obstacles [1,2]. It is commonly accepted that the building sector accounts for around 40% of the world's carbon dioxide emissions [3], even though CO_2 emissions were reduced by 22% between 2008 and 2021 globally [4]. The interest in zero-energy buildings has been consistent, whereas the interest in green or sustainable construction has been decreasing recently. To take on a holistic perspective and optimize both the procedures and the materials [5] used in the building industry, it is important to use methods and approaches that simplify this analysis. The life cycle assessment (LCA) is one of the most popular methods to support sustainable processes. An LCA applied to buildings allows for the evaluation of their environmental impacts during the whole life cycle. However, traditional LCA studies examine the impact of a building over a single service life. On the other hand, components and materials may have several distinct use cycles during the course of the building's lifespan [6]. In the recent European standard on Environmental Product Declarations (EN15804, 2012) [7], LCA methods play a fundamental role, and rules are given to define which phases of the product life cycle have to be considered, how to calculate impacts, and how to compare different products, which all contribute to the evaluation of materials with multiple cycles with short lifespans in the context of the circular built environment [8].

The goal of this publication is to review and offer a critical perspective on the current approaches to integrate a LCA and circular building design (CBD) in the South Asian countries India, Pakistan, and Bangladesh. In particular, this review will investigate whether (and how much) an LCA can support the implementation of a CBD or not.

The structure of this paper is as follows: First, a brief introduction to LCA and CBD is presented. Then, the methodology used to carry out the systematic literature survey is given, followed by the presentation of the selected studies to extract useful information linked to LCA buildings and building materials, the certification of sustainable or green buildings, and the awareness of sustainable buildings. Finally, a section that illustrates the state of the art of CBD in particular countries along with the identification of some of the enablers for CBD from the selected literature is presented. An overview of the major conclusions drawn from the chosen studies is provided in a brief discussion at the conclusion of each section. The primary findings of the literature review are expanded upon in the final section, along with some recommendations and opportunities for future research.

1.1. Life Cycle Assessment

LCA is becoming more widely acknowledged as a cutting-edge methodology to sustainability in the construction sector. LCA is a methodology used to assess resource use, energy use, waste generation, and many other global environmental impacts throughout a project's lifespan [9–26]. The LCA method helps to better visualize and provide answers to questions like what kind of material or constructive process can make a building more sustainable? The promotion of sustainable principles in the relevant industrial sector, both in developed and developing countries, becomes extremely important for planetary sustainability [27].

The LCA method includes processes that evaluate material and energy flows. Following that, the global and/or regional impacts (e.g., global warming potential and acidification) are estimated using the determined input and output flows. This method is widely used in the construction industry, as well as in other industries, to assess the environmental effects of building materials and buildings [28]. To conduct an LCA research, detailed data about the building must be collected, including data regarding the building materials used, the building process, the facility usage phase, and the expected end-of-life scenarios (ISO 14040:2006; ISO 14044:2006) [29,30].

Different tools implement the LCA methodology at various levels of detail. LCA tools can help carry out studies more quickly, easily, and precisely than manual computations. LCA tools can also support the user in comparing various design ideas, materials, and situations based on environmental performance and costs. Evidence-based suggestions and reports can be obtained by using LCA tools, demonstrating the worth of sustainable construction approaches. Table 1 shows some of the most frequently used LCA tools, along with links to their respective websites [27,31]. Due to the need to perform such analysis in a timely fashion, suitable graphical user interfaces provide valuable help to the final user.

Table 1. Summary of most frequently used life cycle assessment tools [27,31] (accessed on 4 December 2023).

Tool Name	Website	Year	Developer	Country	Scope
Athena	www.athenasmi.ca	1997	Athena Sustainable Materials Institute	CA	Simplified LCA
GaBi	www.sphera.com	1992	Sphera	DE	Database and LCA
SimaPRO	www.pre.nl	1990	PRé Sustainability	NL	Detailed LCA
Umberto	www.ifu.com/umberto	2003	Institut für Umweltinformatik	DE	Simplified LCA
OneclickLCA	www.oneclicklca.com	2011	Oneclick LCA	FI	Simplified LCA
OpenLCA	www.openlca.org	2007	Green delta	DE	Detailed LCA

1.2. Circular Building Design

Building-construction-related environmental impacts can be resolved, or at least better understood, thanks to the circular economy (CE) [32,33]. Circularity in buildings is accomplished through narrowing, delaying, and closing resource loops to improve the use of resources now and in the future [34,35]. "Narrowing" refers to significantly reducing and making effective use of resources. "Delaying" focuses on the temporarily prolonged use of resources and the delayed need for new ones. "Closing" deals with the idea of cycling resources once they are used in the system and moving towards closed-loop processes.

In the construction industry, there is not a single accepted definition of CE [36], and the idea covers a wide range of diverse design approaches [33]. Consequently, the design of circular buildings has a wide range of alternatives [37]. Since the LCA methodology helps to identify the environmental impacts of products and services, it also simplifies CE decision making [33]. When used at the beginning of the design process, LCA has the greatest potential for lowering the environmental impacts of buildings [38,39].

However, the adoption of a truly circular design method and processes still seems far from being implemented both at the design stage and during construction [36]. On the basis of LCA results, design guidelines can be presented to support the construction industry in developing circular building components [40]. Maximizing the utilization of existing resources while minimizing the waste output from buildings and their environmental impact are included among the most desirable design aims to achieve circularity in buildings [41].

2. Methodology: Systematic Literature Review

In this study, a systematic literature review (SLR) approach is followed, supported by a well-acknowledged methodology [39]. Using the predefined methodology of SLR makes it advantageous and easily repeatable compared to a generic literature review. SLR starts from some scientific questions that require answers. The criteria of inclusion and exclusion for the studies are set, and then a critical review follows. Finally, discussions and conclusions are drawn, possibly identifying research gaps that deserve further investigation.

The main research question for the present study is to investigate what current approaches are present in the literature to integrate LCA and CBD in the construction sector of South Asian countries (Pakistan, India, and Bangladesh). Some other related queries are also reviewed, including the use of input data for LCA, limitations of existing studies, specific methods used while applying LCA to buildings and building materials with reference to South Asian countries. Also, the potential of implementing the circular building approach is discussed in this paper.

As said above, the SLR follows an established process which starts from the definition of the research question, from which the relevant keywords to be used in the database query will be extracted. In this case, the correlation between the LCA and CBD with reference to Pakistan and other South Asian countries represent the research question. Hence, the selected keywords used to query the databases included LCA, CBD, building sustainability, circular economy, and circular construction in Pakistan, India, and Bangladesh, specifically.

The above keywords were searched in paper titles, abstracts, and keywords lists. The databases selected for the research were Web of Science and Scopus.

Once the databases returned the list of articles that responded to these keywords, the results pertaining to different databases were then merged and examined to remove any duplicate results. A title-based preliminary screening was conducted to eliminate those that did not match the topic (Figure 1). The second step was carried out by reading the abstract for a better understanding of the actual contents. Then, the remaining research articles were read in detail to summarize their contents and extract useful data. Finally, the in-depth analysis of selected articles was completed. A few conference proceedings, book chapters, and other articles were included in the analysis for their relevance to the topic. A snowball approach was also applied to collect supplementary relevant literature by reviewing the references cited in the identified articles. Overall, 71 papers were finally analyzed, distributed in time between 2006 and 2022, as shown in Figure 2.

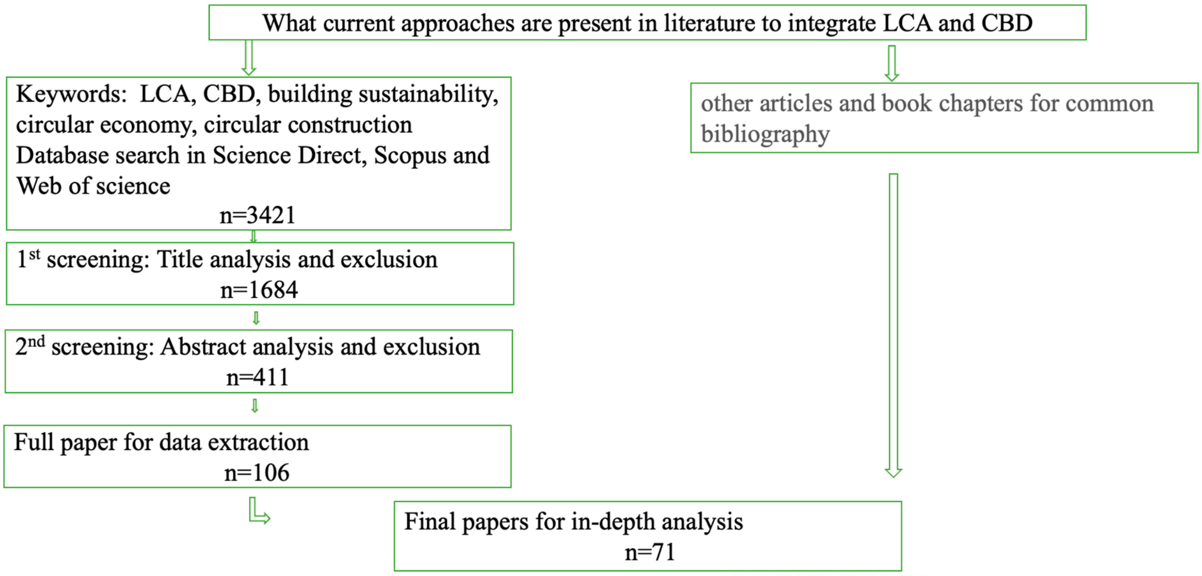

Figure 1. Description of systematic literature review methodology.

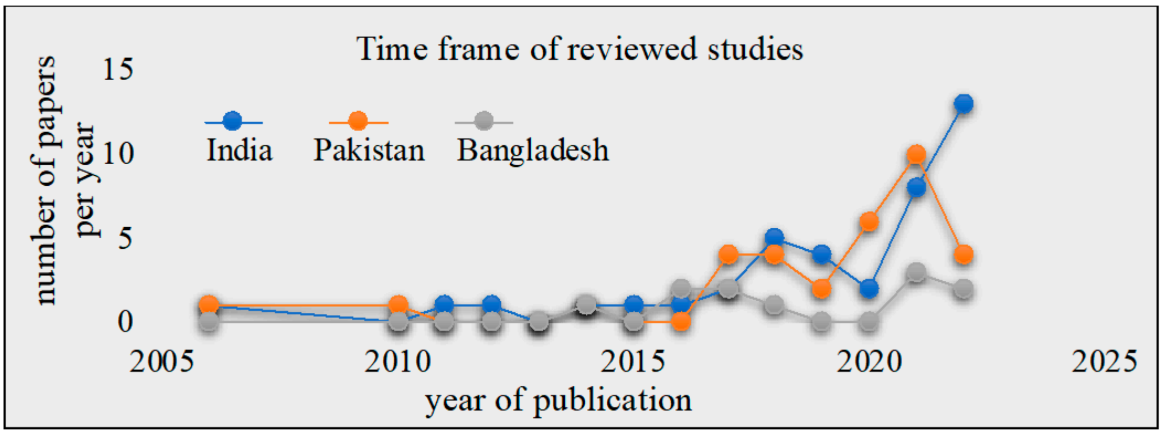

Figure 2. Publication timeframe of reviewed studies.

The initial review revealed the diversity of research in the selected literature. This was the reason behind the idea of categorizing the literature into different sub-topics, each with a specific scope. This review was consequently subdivided into five distinct areas to be fully analyzed and studied, as shown in Table 2.

Table 2. Description of the research questions used to group the literature review.

Question	Scope
How was LCA implemented in selected research papers dealing with construction materials?	Point out procedures, limitations, tools, and inventory databases used in the surveyed literature to perform LCA of building materials
How was LCA implemented in selected research papers to assess whole building environmental impacts?	Point out procedures, limitations, tools, and inventory databases used in the surveyed literature to perform LCA of whole buildings
What is the awareness level about circular building design and use of LCA methods to support it?	Identify if and how professionals and industry involved in constructions are aware about circular design, sustainability, and tools available to achieve such results
Are there any building rating frameworks, standards, or regulations that can support circular design and use of LCA in building design?	Analyze the state of the art of building certification/rating in the selected regions and their use of LCA methods or CBD principles
Is circularity considered in building design? And how?	Identify if and how circularity principles are used in practice when designing and constructing buildings
Is LCA used to positively support circular building design?	Identify if and how LCA is used in practice as a method to support circular design and make effective choice of materials and processes

3. Results and Discussion

3.1. Procedural Aspects in LCA-Based Evaluation of Building Construction Materials in Southern Asia

Building materials and their environmental impacts are evaluated in the construction industry using the same LCA methodology [14,21,42–44]. LCA is a useful method for examining the environmental profiles of products and processes throughout the course of their lifetimes [12,45]. SimaPro, Gabi, and OpenLCA were found to be the most common tools to perform LCA on different construction materials in South Asian countries [14,20], while the life cycle inventory database used was always Eco-invent.

The selection of the "functional unit" to be analyzed (i.e., the quantity of a product or product system needed to ensure a given performance in its end-use application) is a key point in any LCA analysis to ensure good comparability of the results. The functional unit for the LCA varies according to the selected construction material. For example, the authors of [46] used one kilogram of brick as a functional unit to assess the environmental impacts generated in brick kilns in Pakistan. Garcez et al. [47] considered a structural system of a pavement as the functional unit to assess the environmental impacts and service life of a concrete building. The surface areas of stainless-steel slag blocks and ordinary Portland cement blocks have been used as functional units by Di Maria et al. [45] to assess and compare the environmental performances of conventional and modified block materials used in building construction. The total surface of four walls (fired clay brick masonry, reinforced concrete-based wall, concrete block masonry, and stabilized soil block masonry) has been used as a functional unit by Galán-Marín et al. [14] to calculate the embodied energy and global warming potential of conventional brick and natural earth stabilized blocks. Kumbhar et al. [21] assessed harmful impacts on the environment and health during brick production by considering 1000 bricks as a functional unit. Similarly, an environmental sustainability assessment of wooden furniture production was conducted by using one conventional wooden furniture set as a functional unit [48]. Among the selected studies, the LCA of the building construction materials was carried out by using either a cradle-to-gate ([21,46–48]) or cradle-to-grave ([14,20,45]) analysis.

The most frequently considered impact categories used in the selected literature ([14,21,45–48]) are acidification, eutrophication, global warming potential, ozone layer depletion, human toxicity, and freshwater toxicity for the LCA of materials, as shown in Table 3. Only ref. [20] carried out an embodied energy analysis of the materials used in walls during construction.

Table 3. Summary of reviewed papers dealing with LCA of building materials.

Study	Material	Tool	LCA Stage	Functional Unit	Impact Category	Purpose	Outcome
[48] Pakistan	wooden furniture	SimaPro	Cradle to gate	one conventional wooden furniture set	AD, AE, GWP, OLD, HT, FW, AET, MAET, TE, PCO	Use of wood-based furniture may have an impact on the environment	The uses of gasoline in a generator, wood preservative for polishing and resisting insect attacks, and textile in sofa sets had the biggest contributions
[46] Pakistan	brick	SimaPro	Cradle	1 KG brick	GWP, SOD, IR, OF, HH, FPMF, TE, LU,	Financial statistics and the environmental effects of three distinct brick-making methods	Hoffman kilns in Pakistan can lead to lower emissions, improved resource efficiency, increased sustainability, and better brick quality
[47] India	concrete and reinforcing steel	OpenLCA	Cradle to gate	structural system of a four-pavement	DAR, AP, EP, SOD, CC, PO (summer smog), MAE, FWAE, HT, TE	Using the concrete's compressive strength as a green approach could improve the sustainability of a specific RC construction	Structural design criteria and material selection have significant impacts on the durability and environmental impact of reinforced concrete structures
[45] India	stainless steel slag blocks ordinary Portland cement block	Gabi	Cradle to grave	1 m^2 of concrete blocks	AD, AP, EP, FWAE, GWP, HT, MAE, OLD, POC, TE, EE, GWP	To evaluate the environmental advantages and cost of valorizing steel waste to create a new binder of construction materials	Production of stainless-steel slag blocks can reduce some of ordinary Portland cement concrete's negative environmental effects
[14] India	brick masonry	Gabi,	Cradle to grave	total surface of walls	EE, GWP	Assess conventional and eco-efficient brick materials	When the span between walls widens, the final LCA values contradict further
[21] India	process of brick production	SimaPro	Cradle to gate	1000 bricks	Carcinogens RO, RI, CC, OLP, EP, AP, EP, LU, Minerals, Radiations	Brick's environmental performance	It is necessary to switch to more environmentally friendly technology

Construction materials contribute to most of the harmful outcomes on the environment included in LCA, which also allows for the consideration of their effects throughout time. LCA methods can be used to calculate and compare the environmental effects of nearly every material, provided that information about the fabrication processes is available [46]. In the selected literature, the authors carried out LCAs on different materials used in the construction of buildings in India and Pakistan, while limited contributions were found for Bangladesh. Most of the selected papers pointed out the limitations of a commercial database for South Asian countries. So, using other available databases was the only option to perform an LCA.

The majority of LCAs performed on Indian systems or products used databases that do not support regional Indian products and materials [19,49–54]. A national database specifically for South Asian countries has not yet been launched by their governments or any other related body. This creates difficulties for LCA research in developing countries and it represents the major limitation of the existing studies, providing the first answer to the questions raised in the present study. The selection of the LCA method depended on the availability of tools in the context of the research, while the functional units, which also varied a lot, were adapted to the function and specific features of the materials investigated.

Finally, a recurring recommendation in the selected literature is to replace conventional materials with reusable or waste-based materials to reduce the environmental burden. Contractors might have the opportunity to examine the environmental effects brought on by building materials if an LCA analysis was carried out prior to the beginning of any construction. Alternate building materials with less negative environmental effects might then be used to reduce the effects.

3.2. Use of LCA in the Assessment of Buildings' Environmental Impacts

A significant number of studies have been carried out to assess the environmental impacts produced during the life cycle of buildings (Table 4), and most of them relied on a life cycle assessment to provide quantitative data on the environmental impacts generated during the construction of a building from the raw materials extraction phase to the end-of-life phase ([12,13,18,19,23,24]).

Table 4. Classification of LCA in buildings.

Study	Building	Tool	LCA Stage	Functional Unit	Impact Category	Purpose	Outcome
[2] Pakistan	institutional building	SimaPro	Cradle to gate	m^2 floor area	HT, EP, WD, GWP, FFC, POCP, AP, MD, ODP	To identify the most environmentally damaging building materials during building's life cycle	Glass and chipboard are the main contributors to the environmental effects
[13] Pakistan	educational building	ATHENA	Cradle to grave	m^2 floor area	GWP, AP, HH, EP, ODP, SP, Total Primary Energy	To assess overall ecological impact over its life cycle	Building use phase contributes the most in the ozone depletion potential
[19] India	research laboratory	Pareto analysis	Cradle to grave	Total floor area (515 m^2)	EA, EP, HT, HHC, HHR, EQ, ODP, EP, MT, CC, FF, ME, CO_2 emissions	To estimate the quantity of CO_2 emissions that must be removed from the atmosphere to achieve net-zero carbon status	Emissions from cement and steel were high; even though a building operates at a net-zero annual impact, the building generates 866 tCO_2e of CO_2 over its estimated 60-year lifespan
[1] India	residential building	OpenLCA	Cradle (production only)	Whole Building	EA, EP, HT, HHC, HHR, EQ, ODP, EP, MT, CC, FF, ME,	Effects of the construction phase on the environment	Greatest environmental impact comes from masonry (bricks)
[21] India	residential building	One Click LCA	Cradle to grave	--	GWP, AP, EP, OLD, formation of ozone of lower atmosphere	Comparison of the environmental effects of conventional and alternative building materials over the duration of a building's life	External walls and concrete slabs had the most negative effects on the environment
[12] India	PV systems (with and without cooling	Umberto NXT	Cradle to grave	125 w electricity generation	CC, MD, OLD, YA, WD, EQ, HH, NRD	Environmental performance for forced cooling Comparative LCA of the standalone Pv and PV/Thermal (T) system coupled with Earth Water Heat Exchanger	In terms of environmental and energy performance, large PV/T + EWHE=based power plants would be more sustainable
[22] India	residential building	GaBi	Cradle to grave	-	ADP, AP, EP, GWP, HTP, POCP.	LCA framework has been used to design an impact assessment model for a residential building	Cement, steel, and bricks were among the top 3 materials that had significant negative impacts during building construction and operation
[25] India	institutional building	SimaPro	Cradle to gate	m^3 floor area	GWP, AP, OLP, HHC, HHP, EP, WI, Smog, EP, EuP, IAQ, NRD,	Analyze the ecological imbalance, the effects on the environment, and the shortening of the buildings' overall lifespan	The most significant contributions to all impact categories are Italian marble, steel, concrete (with fly ash), and masonry
[26] India	institutional building	--	Cradle to gate	m^2 floor area	GHG emissions	Life cycle environmental assessment of the building to calculate energy consumption and GHG emissions	For all three stories, the building's RCC framework and steel are the biggest contributors to greenhouse gas emissions
[18] Bangladesh	residential building	One Click LCA	Cradle to grave	m^2 floor area	HHC, GWP, non-carcinogenic, energy demand	Quantification of environmental impacts of a residential building	Most of the carbon emissions in typical suburban residential buildings with no more than three stories are likely caused by the materials used in the construction of floor slabs, walls, roofing decks, beams, and roofs
[23] Bangladesh	residential office educational building	--	Cradle to grave	m^2 floor area	Carbon emissions	To assess and contrast the carbon emissions and energy usage of three types of buildings	Operational phase primarily causes the highest carbon emissions, and materialization and operation are accountable for 97% of all emissions Commercial buildings consume far more energy than residential and educational buildings because they need so much operational energy

Applying LCAs to whole buildings may be valuable under many points of view, from understanding (and minimizing) the overall impact that the building process may have to identifying the processes and components that mostly affect those impacts, and, thanks to building information models (BIMs), to identify the optimal maintenance strategies.

In the selected literature, LCAs have been performed on different categories of buildings such as residential, office, institutional, and educational buildings. The largest number of studies involved residential buildings ([1,18,23,24]), followed by institutional buildings ([19,25,26]) and educational buildings ([13,23]). Residential buildings were preferentially selected because of the ease of obtaining data and also the use of simpler building processes (as residential buildings are inherently simpler than commercial or institutional buildings).

In terms of functional units, 70% of studies (Table 4) used the floor area covered by the building, expressed in square meters (m^2). While for individual building materials, production until the end-of-life phase was assessed frequently in the literature, while for whole buildings, this appeared to be unlikely, as the application of an LCA requires a much larger (and difficult to collect) set of input data. As no local database exists, researchers have been using the Eco-invent database in developing countries. With reference to tools, SimaPro [2,18,25], GaBi [22], ATHENA [13], Pareto analysis [19], OpenLCA [1], OneClick LCA [24], and Umberto NXT [12] have been used in the selected papers to perform LCAs.

Table 4 summarizes the selected papers, grouped according to the impact categories they used. The most common impacts selected by studies on building construction materials are global warming potential and CO_2 emissions ([1,2,13,18,19,23–26]). Among the other impact categories, ecotoxicity, human toxicity, natural resource depletion, and ozone depletion were frequently assessed. Varun et al. [25] selected another group of impacts, including water intake, habitat alteration, and smog.

In Pakistan and Bangladesh, building assessment procedures are relatively uncommon. The selected studies pointed out that a greater number of LCA studies are carried out in India (Figure 3) to evaluate environmental impacts during the building construction process. R-studio was used to analyze the co-occurrence of keywords associated with the LCA-based research for all three countries. However, only India exhibits a significant number of studies in this field. The analyses of embodied energy and emissions in life cycle assessments were the primary focuses of those studies. Due to a lack of local inventory databases, LCA studies in India were less focused on the construction sector compared to other fields, and the majority of LCAs performed on Indian systems or products relied on databases that do not support local Indian materials and products [19]. Therefore, both local and imported building materials were used in the construction of buildings, as they have similar data inputs.

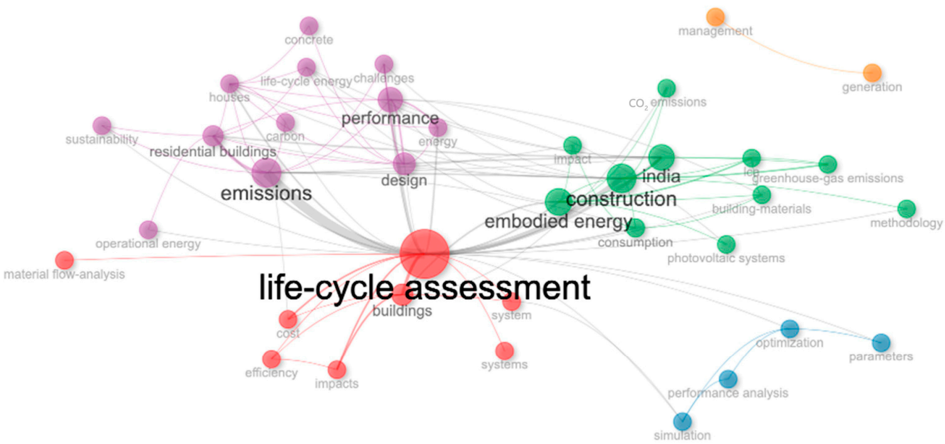

Figure 3. Co-occurrence of keywords in the selected literature (India).

With reference to Bangladesh, the literature survey did not return systematic research on this potentially profitable method of material selection evaluation and the examination of their environmental impacts. This could consequently be a topic worth being explored by future research, possibly also contributing to address climate change and provide sustainable building design and construction in this country [18].

The Pakistan Green Building Council is a recognized member of the World Green Building Council [55]. The Sustainability in Energy and Environmental Development guidelines were published in 2016 [56,57], and they are being used for the certification of construction projects in a prescribed rating criterion. Nevertheless, the country is lacking in studies that evaluate and assess the building impact before construction. A small number of studies have been conducted to assess the environmental profiles of building materials and for the carbon footprint assessment of products and systems ([2,9,10,13,20,58,59]). Even though architects claim that their structures are environmentally beneficial, this cannot be proven until an LCA is carried out [13]. For the upgrade and execution of sustainable development assessments in the construction sector, policy and legal guidelines must be developed [56].

3.3. Awareness of Sustainable Building Construction

Understanding the level of awareness of sustainable building construction (and related problems) in the selected South Asian countries is an essential step towards a more comprehensive analysis of the promotion of CBD strategies. The analyzed studies in the literature focusing on the awareness topic are given in Table 5. Several studies have been reviewed to point out the awareness level about sustainable building construction within the local population and construction industry.

Table 5. Studies on the awareness of sustainable building construction.

Study	Purpose	Outcome
[60] Pakistan	To examine local construction market awareness of green buildings in Pakistan	Designers and builders in Karachi's construction sector lack knowledge about energy-efficient and environmentally friendly structures and are unaware of the critical green building materials.
[61] Pakistan	To analyze the market adoption of sustainable housing in Pakistan and estimate their desire to pay for sustainable housing	The price premium has a significant impact on people's willingness to pay for sustainable housing.
[62] Pakistan	In-depth prospects and obstacles relating to sustainable residential construction in Pakistan are comprehensively investigated	Due to limited knowledge and awareness, contractors and architects are not equipped to design or build a green dwelling.
[63] Pakistan	To explore the impediments preventing the use of green building and approaches to support this strategy in Pakistan	The biggest obstacle is the absence of public awareness about the significance and benefits of adopting green building methods, which is followed by a lack of government incentives and insufficiency of green building norms and regulations.
[64] India	Creating a mobile app and a general standard to select suppliers of low-emission construction materials	The designed user-friendly mobile application will raise public knowledge of issues including energy, the environment, ecology, and sustainable development.

The awareness about green buildings in Pakistan among local construction market stakeholders was examined in ref. [60]. The data were collected through questionnaire surveys related to priorities and awareness levels in the construction business in the city of Karachi for green building constructions. Furthermore, an analysis was conducted on a focus group, and professional interviews were conducted with individuals involved in local construction projects. The results showed that increasing the indoor environmental quality, protecting the environment and natural resources, and conserving energy were the key forces behind the development of green buildings. Likewise, there was an absence of understanding about green building construction processes and regulations, as well as complaints of a lack of government assistance.

Khan et al. [61] analyzed the market adoption of sustainable housing in Pakistan by characterizing the profiles of possible customers and estimating their desires to pay for sustainable housing. A total of 354 homebuyers were surveyed to identify willingness to pay. Additionally, to investigate the relationship between descriptive factors and willingness to pay for sustainable housing, a hierarchical Bayesian model of an adaptive choice-based cluster analysis was used. The findings revealed that while income level and environmental knowledge are adversely correlated with the willingness to pay (due to less affordability), demographic parameters including age, gender, and literacy level are favorably correlated with it. Among other home characteristics, energy efficiency was also the one with the highest comparative relevance.

Thorough prospects and obstacles relating to sustainable residential construction in Pakistan were comprehensively investigated in ref. [62]. The study also included the perceptions of the users and barriers faced by practitioners in industry to move from conventional residence to green residence. Conventional dwelling practices were compared with the LEED-certified dwelling in Pakistan. The results suggested that due to limited knowledge and awareness, contractors and architects were not equipped to design or build a green dwelling.

Azeem et al. [63] identified the key drivers and barriers in Pakistan's local construction for the adoption of green building by studying the literature, conducting a questionnaire survey, and conducting in-depth interviews with Pakistani construction industry professionals. The key barriers identified were a lack of public awareness regarding the importance and benefits of green building methods as well as a lack of governmental incentives, rules, and regulations for the construction of green buildings. Governmental financial incentives and penalties (in the form of soft loans and taxes) for encouraging the use of green building practices were identified as the most needed step in promoting the adoption of green building practices. Furthermore, increasing public knowledge about green initiatives through seminars, workshops, and conversations was expected to result in a beneficial shift in society towards sustainable building.

Kumar et al. [64] created a mobile application and a general model to select suppliers of low-emission construction materials, hoping that the designed user-friendly mobile application might raise public knowledge of issues including energy, the environment, ecology, and sustainable development.

Among the surveyed literature, the maximum number of research articles was published in the context of Pakistan on the awareness of sustainable building construction. Significant barriers to and drivers of the willingness to accept (sustainable construction) were identified, and the importance of sustainable building construction and awareness for architects, planners, contractors, market professionals, and stakeholders was thoroughly analyzed. Indian researchers have been working on a different perspective to raise awareness on these topics, taking advantage of a mobile application to spread the knowledge of carbon emissions and energy efficiency among common people.

In order to promote awareness and as a component of green banking, Bangladesh Bank introduced green financing, which can significantly aid in the transition from resource-intensive businesses to low-carbon businesses [65]. The literature shows that several efforts are being made to spread the benefits of green and sustainable construction in the selected three countries of South Asia. Still, developers and architects are not mindful of the responsibility they can play in designing and constructing sustainable buildings [66].

3.4. Certification of Sustainable Building Design

Since sustainability certification systems (SCSs) played a major role in increasing the acceptance of sustainable new construction in Western countries, the accurate evaluation of building performances may also be essential to facilitating this transition in South Asian countries. LCA is an effective method to better support green construction management from a broader perspective, such as material selection and implementation in buildings, and, along with other sustainability metrics, it has already been included as an evaluation criterion in a large number of certification systems. The integration of CE into the certification process has been a recent focus of European certification systems. Investigating the role of LCA in certification systems in the selected countries is the main subject of this section. Table 6 shows the list of studies carried out on the topic of the certification of buildings in the selected countries.

Khan et al. [56] developed and validated a comprehensive framework for the construction of rating tools considering societal and governmental factors by conducting in-depth interviews with a variety of Pakistani stakeholders. Following a qualitative examination of the interview data, a final framework with key indicators reflecting each of the five sustainability characteristics was developed. The study suggests that this methodology can make it easier to gauge how well the sustainability evaluation framework will function.

Ullah et al. [67] created a framework for evaluating the sustainability of residential buildings in Pakistan that is specially designed to put a greater emphasis on social issues. The results showed that environmental (61.5%), economic (11.5%), and social (27%) aspects make up the complete framework. If used, the framework would assure sustainable urban areas and societies with manageable domestic housing units. An attempt was made by the authors of [68] to create a building performance score (BPS) model for sustainability that considers the three key elements of environmental, economic, and social concerns. Like in an LCA, the stages of the project life cycle are identified, and each stage is then evaluated while considering key elements. The findings suggested that a sustainable building is primarily influenced by several factors, including topography and climate change, construction workers' health and safety, project management consulting, risk management, security actions, and solid waste management.

Francis et al. [69] introduced a methodology framework for Dynamic Life Cycle Sustainability Assessment (D-LCSA) based on system dynamics, and it can take into account dynamic variations in building attributes over time and capture interactions between various sustainability indicators. The results of the preliminary testing and performance of the framework showed that it is crucial to consider the dynamic characteristics of the building. The study also emphasized how crucial it is to base sustainability decisions on the interrelated systemic behavior of the many sustainability indicators rather than just the performances of single indicators.

Srivastava et al. [70] made an effort to address the shortcomings of existing sustainability assessment tools by creating a methodological framework for the life cycle sustainability assessment of construction that incorporates triple bottom line and decoupling concepts. The triple bottom line principle relates to the idea of combining economic and social well-being with minimal or reduced environmental pressure. Similarly, the "decoupling" principle aims at achieving continued socio-economic growth while diminishing environmental impacts. Numerical descriptors and calculation procedures are proposed to complement conventional LCA methods.

Jamal et al. [71] investigated Bangladesh's potential for green building by analyzing LEED-certified buildings in that country, concluding that the adoption of green building technologies might help both the government and the next generations to experience significant ease from the energy crisis.

Reza et al. and Bahauddin et al. [65,66] found, after looking at most of the buildings in Dhaka, that architects and developers are still oblivious to the roles they may play in creating sustainable and smart structures. Developers and clients put continuous pressure on architects to plan multi-unit buildings with an efficient use of space and cost-effective construction. From this viewpoint, Bangladesh must spend a lot of effort ensuring sustainability when designing, planning, and building structures.

The USGBC's LEED certification is the main source of green building concepts that are acknowledged in Bangladesh. Given the limited size of the sustainable building sector, the current incentives seem insufficient to spark a successful green industrial development [72]; nonetheless, sustainable site assessment criteria and points have been proposed for Bangladesh [65]. The comparison between India, Malaysia, and Sri Lanka helped authors to propose sustainable site and management initiatives for Bangladesh that are capable of promoting the construction of green buildings.

Table 6. Studies on certification of sustainable building design.

Study	Purpose	Outcome
[56] Pakistan	to create a comprehensive framework for constructing grading tools that considers societal and governmental factors	The framework included significant indicators that reflected all five sustainability dimensions.
[67] Pakistan	to create a framework for evaluating the sustainability of residential buildings that is specially designed to put a greater emphasis on social issues	If used, the framework would ensure sustainable urban areas and societies.
[68] India	an attempt to develop a score model for building performance without distressing the environment	A sustainable building is primarily influenced by several factors, including topography and climate change, construction workers' health and safety, project management consulting, risk management, security measures, and solid waste management.
[69] India	introduce a methodology framework for Dynamic Life Cycle Sustainability Assessment that is based on system dynamics and can take into account dynamic changes in building attributes over time and capture interactions between various sustainability indicators	The results of the initial testing and performance of the framework show that it is crucial to consider the dynamic characteristics of the building.
[70] India	the idea of sustainable construction is introduced as a classification of impact and well-being decoupling	The suggested methodological framework ensures a monitoring mechanism for the proposed TBL-based life cycle sustainability approach, employing decoupling indicators in addition to incorporating the technique.
[22] India	a life cycle assessment (LCA) framework has been used to design an impact assessment model for a residential building	After applying normalization and weighting, a single combined score reflecting the total impact of the building was created.
[71] Bangladesh	to comprehend Bangladesh's potential for green building	Bangladesh will experience significant ease from the energy crisis because of the adoption of green building technology.
[73] Bangladesh	by identifying key barriers, this study illustrates the scenarios of rapid population increase and urbanization and the significance of green building in Bangladesh	The construction of new environmentally friendly projects and the renovation of old buildings, which will also be less expensive, are necessary to combat climate change.
[66] Bangladesh	to solve the problems with sustainable building and offer a smart, sustainable design	Architects and developers are nevertheless oblivious to the parts they may play in creating smart and sustainable structures.
[72] Bangladesh	to develop a Sustainable Site and Management assessment system for Bangladesh's built environment	Many methods and resources employed in Bangladesh today contribute to environmental degradation.
[65] Bangladesh	to analyze the social, economic, and environmental benefits while providing a general summary of the current situation of the actions implemented for a green industry	The current incentives are insufficient to initiate successful green industrial development, given the limited size of the growing sector.

Sustainability assessment methods and frameworks are actively adopted worldwide for the evaluation of sustainable building designs. Consequently, guidelines have been developed to support building design and its certification in terms of sustainability performance. The statuses of green building certification in Pakistan, India, and Bangladesh have been assessed. However, as in the case of India, where the Leadership in Energy and Environment Design-Indian Green Building Council (LEED-IGBC-India) and the Green Rating for Integrated Habitat Assessment (GRIHA-India) rating schemes exist, rating frameworks need to be adapted to specific contexts and conditions, as current research showed that it is quite impossible to follow guidelines developed for a specific region in another region. In fact, a lack of information and a lack of consideration for a regional background may significantly reduce the effectiveness of such tools. The significant observation is the lack of a connection between LCA and certification systems in all three countries. The importance of LCA in the certification process for projects and early decision making has been missing in the surveyed literature. For future research, this could be an important area to explore, and the implementation of CBD practices supported by LCA within certification and rating schemes could be worth being further explored in the selected countries.

3.5. Circularity in Building Construction

In the chosen South Asian countries, little research has been conducted in the field of circular building design and construction. A few studies related to building circularity and circular economy were published in the past four years (2019–2022) by Indian researchers, while no publications were returned by the database query related to circularity in Pakistan and Bangladesh. In the surveyed literature, the concept of circularity was applied in different ways (Table 7).

Table 7. Studies on circularity in building construction.

Study	Purpose	Outcome
[74] India	To illustrate the potential shift to a circular construction sector in India by creating the first practical framework with solid standards for a Circular University Campus (CUC).	Bioclimatic and regenerative building concepts have the potential to drastically modify how the construction sector responds to climate change. Buildings, neighborhoods, and cities can be useful and less destructive to the environment, the user, and the investor if the building industry overwhelms its key barrier and transforms from inefficient, linear assemble methods to circular build principles.
[75] India	To assess the potential for material circularity in the construction industry and compare it with the current situation in India.	Cost, technical viability, and governmental policy are the main forces enabling material circularity, and with coordinated efforts from numerous stakeholders, linear buildings in emerging nations could eventually give way to circular construction.
[76] India	With a relation to the built environment, this study concentrated on India as a growing economy and discussed the possibility of leading the country towards a direction of circularity.	Seven key considerations can lead towards circularity, such as the role of the government, collaborations with private businesses and policymakers, education, investments, increasing incentive capacity, the roles of public and private organizations, and stakeholder participation.
[77] India	To promote the circular economy, this article aims to comprehend consumers' cross-cultural desire in purchasing reconstructed items.	Indian customers exhibit utilitarian purchasing habits, an anthropocentric approach towards waste disposal, and a lack of commitment to rules. The government should create policies that encourage the use of reconstructed commodities at the policy level. Firms could take use of marketing and advertising initiatives to raise public knowledge of reconstructed products.

One of the studies explored the potential shift to a circular construction sector in India by creating the first practical framework for a Circular University Campus (CUC) based on a real-world illustrative case study project [74]. The study was carried out step by step. The first step was to demonstrate the environmental, social, and economical benefits of a circular construction industry by means of a thorough literature review. In the second step, the applicability of the developed guidelines for a CUC was tested on the selected case study. In the third and concluding step, the guidelines were applied to create "Project-Specific Circular Building Indicators" for a housing complex at a university campus and to improve the suggested design using bioclimatic and regenerative design techniques. Solar irradiation was used to optimize solar shadings and ventilated roof technologies. Furthermore, along with the domestic hot water and potable water requirement, a complete LCA was carried out in order to evaluate the carbon footprint and potential for the circularity of the selected case study. The results showed that building designs that are bioclimatic and regenerative, switching from linear to circular building methods, have the potential to significantly alter how the construction industry responds to climate change.

In another study [75], the potential for the circularity of materials in the construction industry was explored and compared with the current situation in India. A mixed methodology was used, in which a literature survey was used to identify the potential of material circularity of building materials (bitumen, concrete, and steel). Furthermore, the current situation was analyzed by means of interviews and on-site annotations. Based on the building stages and the associated circular methods, a model was defined to enable material circularity. The results showed that a varied range of paths are available to incorporate circular economy into material management, including product life extension, repair and maintenance, material reuse, material substitution, and recycling. The study concluded that cost, technical viability, and governmental policy are the main forces enabling material circularity, and that, thanks to coordinated efforts from numerous stakeholders, linear buildings in emerging nations could eventually give way to circular construction.

With relation to the built environment, another study focused on India—as a growing economy—and explored the possibility of leading the country towards the direction of circularity [76]. The paper started with a simple explanation of the circularity principles while examining what circularity means for the built environment. To emphasize the significance of circularity in the built environment in emerging economies, two case studies from India were provided. As a result, the authors indicated seven key factors that can pave the way to circularity, such as the role of the government, collaborations with private businesses and policymakers, education, investments, increasing incentive capacity, the roles of public and private organizations, and stakeholder participation.

To promote the circular economy, consumers' cross-cultural desire in purchasing reconstructed items was also explored [77]. Firstly, the samples of diverse societies (USA and India) were gathered. Secondly, authors performed two sets of analysis in which the purchase interest of consumers of both countries who were residing in their home countries were investigated. The authors also looked at how sociocultural models affected the purchase interest of reconstructed products for Indian consumers who moved to the USA. The data collection involved in-depth interviews. The thematic data analysis methodology was followed to analyze the collected data. The findings showed that USA consumers had altruistic purchasing tendencies, they were eco-focused in their waste management practices, closely adhered to social and cultural norms, and they had a harmonized outlook towards the environment. Indian customers, in contrast, exhibited utilitarian purchasing habits, an anthropocentric approach towards waste management, and a lack of commitment to rules. Finally, it is concluded that emerging economy governments should enact policies that encourage the use of reconstructed commodities at the policy level. Firms could make use of marketing and advertising initiatives to raise public knowledge of products that were reconstructed or made with recycled materials.

The selected studies were all from India, where researchers have been working on the different perspectives associated with circular construction. The studies focused on the analysis of the current situation of the implementation of circularity in building construction, along with the development of guidelines and the identification of key factors to promote circularity in developing countries. Furthermore, the socio-cultural influences were studied and analyzed based on consumer behavior towards the acceptance of reconstructed building products.

This part of the review answered one of the sub-questions of this research. The literature showed significant activity in the field of construction circularity in India, but Pakistan and Bangladesh proved to be slower in investigating such aspects. This suggests a significant potential for future studies to investigate circularity in building construction industry in South Asian countries.

3.6. Life Cycle Assessment and Circular Building Design

The LCA methodology, according to EN 15804:2012 standards [7], includes different modules (A, B, C, and D) that, in addition to the production (A), construction (B), use and end-of-life (C) stages, also include the possibility to recycle, recover, and reuse (D) building materials, products, or components. In this context, the life cycle refers to all phases of the products' and components' journeys from raw material production to the end of their service lives, or, more simply, from "cradle to cradle". This extended view of the life cycle is relevant to support circular economy in the construction sector, where it is essential to characterize materials with regard to their environmental performances, recyclability, reusability, and recovery potential. This refers to a situation where the application of the LCA method clearly plays a significant role.

Prior to the inclusion of these modules in the LCA methodology, researchers were unable to perform a complete cradle-to-cradle LCA of products and systems. Similar examples can be found in older papers pertaining to the South Asian region. Nevertheless, most of the cradle-to-grave LCA studies are recent and published from 2018 to 2022, except for [14], which was published in 2015. However, the selected literature lacks cradle-to-cradle LCA referring to the investigated geographical area. For an environmental impact analysis of the building sector, several studies ([12–14,18,19,22–24,45]) took advantage of a cradle-to-grave LCA methodology. More in detail, some studies used LCA for building materials (such as concrete block, stabilized soil block, and stainless steel slag) [14,45], while others ([12,13,18,19,22,23,25]) used the LCA method for a whole-building environmental impact analysis.

With reference to studies published in recent years around the world, it was not unusual to find applications of the cradle-to-cradle LCA methodology in building construction technology ([33,78,79]), using LCA to compare different scenarios of conventional and circular building design components. Similar investigations are expected to become more popular in the next years even in the contexts of Pakistan, India, and Bangladesh, offering researchers new opportunities to identify the potential of circular building design.

4. Conclusions and Recommendations

The literature survey that was presented above allowed us to provide answers to the research questions mentioned in Table 2.

The detailed literature review identified that, in the selected countries, the input data used for the analysis of buildings, materials, or systems were taken from the project sites and from the available documents from the contractors. Other than this, the input inventory data used in studies were taken from international databases because the unavailability of databases is a common limitation in all three countries.

Data retrieval proved to be the most significant limitation in the literature. The use of non-reliable databases limited the application of LCA and reduced its impact. In fact, data acquired from manufacturers, contractors, and house/building owners were considered more frequently than data from the life cycle inventory database. For this reason, the researchers often thought that the data used could be invalid and could lead towards different results than expected. Furthermore, other limitations and challenges, like site-specific and microclimate considerations, affected the assessment of the local impacts for the selected region.

Most studies emphasized the need for country-specific databases to overcome the uncertainties in the results of the analysis. In addition, raising awareness about low-environmental-impact materials and construction techniques would be an essential step to promote circularity in the building construction sector. Moreover, public awareness towards sustainable initiatives by means of workshops, seminars, or discussions would result in positive change in the society towards sustainable construction and its benefits. The next most important step in encouraging the adoption of sustainable building practices could be represented by the governmental financial incentives and penalties (soft loans and taxes).

The LCA methodology defined by ISO 14040 [29] and 14044 [30] was more frequently used in the selected literature, following the four main steps of the LCA framework; studies have identified the numbers of environment degrading materials and systems which are used in the construction of buildings in developing countries. In addition to environmental impacts, a limited number of studies discussed the socio-economic impacts as well. The identification of natural resources involved in the building process and the availability of eco-friendly materials were found to contribute to the achievement of circularity in constructions.

Following the aforementioned observations, a number of recommendations and potential directions for future research are summarized here. A wide use of environmental assessment methods could help researchers to identify the most suitable strategies of sustainable construction and design, which can also be adapted to specific countries. Awareness about sustainable practices and the implementation of sustainable practices on a small scale to extended-scale projects need to be further promoted using all available media. Even though construction sector professionals are responsible for the adoption of circular building strategies, individuals need to be engaged to maximize their awareness and willingness to pay for more sustainable and circular buildings. Governments should enact regulations and building codes in which circularity must be a part of buildings' design and construction processes. Public and private companies should work jointly to achieve sustainable development goals and introduce products and services that are less harmful to the environment, and products based on a circular supply chain should be prioritized in manufacturing processes. The non-availability of an inventory database is the main reason behind the limited number of studies in South Asian countries. As a consequence, it was observed that when researchers are not able to carry out reliable LCAs of building materials and processes, then they are also less likely to perform research in the domain of CE. Plenty of materials are available in the selected context to start working on the CBD, but a lack of technologies, poor labor force, and a lack of acknowledgement from governmental authorities are the barriers to start such an environmentally and economically friendly approach.

As previously stated, research on the application of LCA to the study of ecological impacts is still in its beginning and faces a variety of intriguing difficulties in developing countries. Future studies should focus on how to use various evaluation criteria, including LCA and building material performance, so they may be used from the design stage to reduce the consequence of linear construction. Economic conditions play vital roles in the promotion and adoption of new technologies in developing countries. Therefore, locals and practitioners are always in fear of the capital cost of a project before it starts. So, providing methods to quantify economic and financial benefits for clients at the beginning of project development is essential to allow for a better understanding of the value of CBD.

Finally, in terms of future studies, the areas that could benefit from additional investigation are as follows:

- The standardization of LCA inventory databases to prevent results from being distorted depending on the input data. To this purpose, it is important to record the degrading building materials used in the construction and provide alternative materials with circular properties. Investigations are needed on the availability of biodegradable, recycled, and reusable materials and products in the selected countries.
- Investigating building materials is just one way to achieve building circularity. Building processes, maintenance cycles, and de-mounting play equally important roles, and further research on these topics will grant a successful promotion of circular building design strategies.
- More case studies need to be analyzed using the CE framework, and based on the results, CBD guidelines tailored for South Asian nations can be further researched in the future.

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