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SRILANKAN CONSTRUCTION INDUSTRY: A STUDY OF CIRCULAR ECONOMY PRINCIPLES FOR SUSTAINABLE BUILDING PERFORMANCE

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Abstract. The construction sector is one of the most distinct economic sectors in both developed and developing nations worldwide. Energy and raw material usage in emerging countries is rapidly increasing. Sri Lanka is coping with major environmental issues because of the continued development of the construction industry. Sri Lankan construction industry issues have occurred with the unsustainable construction practices due to the linear economy. As a result, Sri Lanka is focusing on sustainability by incorporating circular economy principles into the construction and built environment sectors. Therefore, the aim of the study is to evaluate the current application of the circular economy principle for sustainable building performance in the Sri Lankan construction industry and to provide recommendations for developing circular economy strategies to improve sustainable building performance in the Sri Lankan construction industry. The research used a quantitative research approach. The questionnaire survey was targeted to identify the prevailing issues and the level of applicability of circular economy principles and the sustainability of the Sri Lankan construction industry. Based on the findings, it can be concluded that the lack of awareness, education, and training in sustainable practices during construction projects, the absence of a proper legal framework and enforcement, and the generation of high waste volumes and carbon dioxide emissions are the most prevalent issues in the Sri Lankan construction industry. A sustainable building industry in Sri Lanka can be achieved through promoting green building technologies, improving the legal framework to strengthen the circular economy implementation, recycling of waste, and utilisation of locally sourced eco-friendly materials.

Keywords: *Circular economy, Sri Lankan construction industry, Sustainability.*

INTRODUCTION

The construction industry is described as an industry that engages in tasks like new construction, modification, maintenance, and destruction. Consequently, it is an important industry that significantly affects both the economy and environment of the building and construction industry (Zuo & Zhao, 2014; Norouzi et al., 2021). The construction industry supports the economy, 9 % of Gross Domestic Product (GDP), creates direct jobs, and meets the demands of the inhabitants for facilities and amenities (Zhao et al., 2019; Norouzi et al., 2021). However, construction industry consumes a significant number of resources: 36 % of the world's entire energy use and 50 % of all raw material use (Norouzi et al., 2021), which is identified as the largest user of natural resources in the world. The built environment sector has employed and maintains to employ a non-sustainable, linear economic paradigm centered on the "take, make and dispose" principles (Zu Castell-Rudenhausen et al., 2021). With the industry's adaptation to the linear economic model, there are significant negative environmental effects, including 39 % of energy and process-related emissions and emissions of greenhouse gases at an identical rate, which would result in a critical problem. This causes serious environmental issues throughout the entire lifespan of buildings, particularly during the operational and end-of-life phases.

The emphasis on sustainability and worldwide greening initiatives, including circular economy concept, requires a change of the unsustainable situation in the built environment. The "take-make-dispose" linear production and consumption model, which is endangering sustainability and is getting close to the environmental limits, must be changed by the circular economy framework (Norouzi et al., 2021). Reducing the cycles by recycling waste and materials and decreasing the material loops by creating durable, reusable items are necessary steps in this circular economy direction. As a result, no additional natural resources are required to manufacture the products, and waste is reduced (Guerra & Leite, 2021). Construction industry is the one of the sectors that has the greatest potential for applying circular economy principles and practices to achieve the sustainability of the build environment, particularly by promoting eco-friendly products as well as the technologies. Moreover, using the CE concept in the construction industry encourages the utilisation of sustainable resources to implement sustainable building performance, improves material recovery, and reduces the amount of waste generated unnecessarily and waste that is disposed at the landfills (Akanbi et al., 2018).

Due to the ongoing expansion of the construction sector, Sri Lanka is also dealing with serious environmental problems due to the unsustainable practices of the whole construction phases (Abeydeera et al., 2019). The construction industry in Sri Lanka has exceeded its maximum level of wastage production. For instance, the material wastage is around 25 % of sand, 10 % of ceramic, 14 % cement, 10 % timber, 5 % paint and 20 % of lime (Wanaguru et al., 2022). Hence, it is logical to expect that consumption of resources and waste production will increase in the future as unsustainable construction activity increases. Moreover, it is claimed that the Sri Lankan construction industry is only just beginning to acknowledge circularity principles (Wijewansa et al., 2020). The limited availability of research articles in this field underscores the relatively recent integration of sustainability-oriented concepts, such as circular economy principles, into the Sri Lankan construction industry for enhancing sustainable building performance (Wanaguru et al., 2022). Accordingly, there is a vital need to evaluate the circular economy principles for sustainable building performance in the Sri Lankan construction industry which has not been discussed in detail yet. Therefore, this study aims to evaluate the current situation of the application of circular economy principles to the sustainable building performance of the construction industry in Sri Lanka and provide recommendations to develop circular economy strategies for the improvement of the sustainable building performance in the construction industry of Sri Lanka.

1. LITERATURE REVIEW

1.1. Circular Economy Concept and Principles

The 18th century industrial revolution represented not only the shift from manual to automated manufacturing, but also the beginning of a series of profound social transformations (Tambovceva & Titko, 2017). A linear process is the foundation of the linear economy, which has emerged with the industrial revolution. Since various inputs are available at relatively reasonable costs, the process is typically designed to make it as effective as possible, with maximum throughput and lower production costs (Sariatli, 2017). Currently, all the manufacturing process takes raw materials from the environment and transforms them into existing innovations according to the linear economy, after which they are disposed back into the environment. From the beginning to the end, the linear economy process is sequential, resulting in the depletion of raw materials and the build-up of waste, which raises disposal costs and pollutes the environment. The linear production systems originating from the Industrial Revolution have discharged billions of tons of detrimental pollutants into water, air, and soil, leading to significant ecosystem degradation and biodiversity loss (Tambovceva & Titko, 2017). Therefore, a novel development framework is required to achieve sustainable development, encompassing economic growth, environmental protection, and the enhancement of quality of life for the population (Bonnedahl et al., 2022). With industrial ecology, the concept of the circular economy (CE) originally arose from the search for an efficient way to transform resources into useful materials for other products and processes (Norouzi et al., 2021). CE has drawn more attention from the corporate and governmental sectors as a result of the recognition that moving away from the linear economy system can help resolve the ongoing conflict between environmental sustainability and economic growth.

CE was introduced by Pearce and Turner in 1989; it described the concepts and theories underlying the economics of natural resources and their connections and effects on the conception of how the economy operates. Accordingly, the definition of the circular economy notion varies depending on the perspective. CE was described as the process of preserving goods, resources, and parts for optimum performance and usability across time, within the main objective of reducing waste. The Ellen MacArthur Foundation defines the circular economy as comprising two primary approaches: a Resource-Oriented Approach, which prioritizes closed-loop resource utilisation, energy recovery, and waste management; and an Economic-Oriented Approach, which centres on resource conservation and reuse to yield economic and social advantages throughout system components. As per their assertion, CE is mostly focused on eco-effectiveness rather than comparing to eco-efficiency, which is a great focus for systems thinking and designing. Figure 1 illustrates how the narrowest loops are employed to create value in both the technical and biotic nutrient cycles, following MacArthur's diagrammatic definition within the CE framework. The highest-value loop in the technical cycle involves product repair and maintenance, followed by reuse, redistribution, remanufacturing, refurbishing, and ultimately recycling (Beaulieu et al., 2015). The biotic cycle's loop with the greatest integrated value is the manufacturing of biochemical raw material, followed by the utilization of agricultural amendments and biofuels as a source of renewable energy.

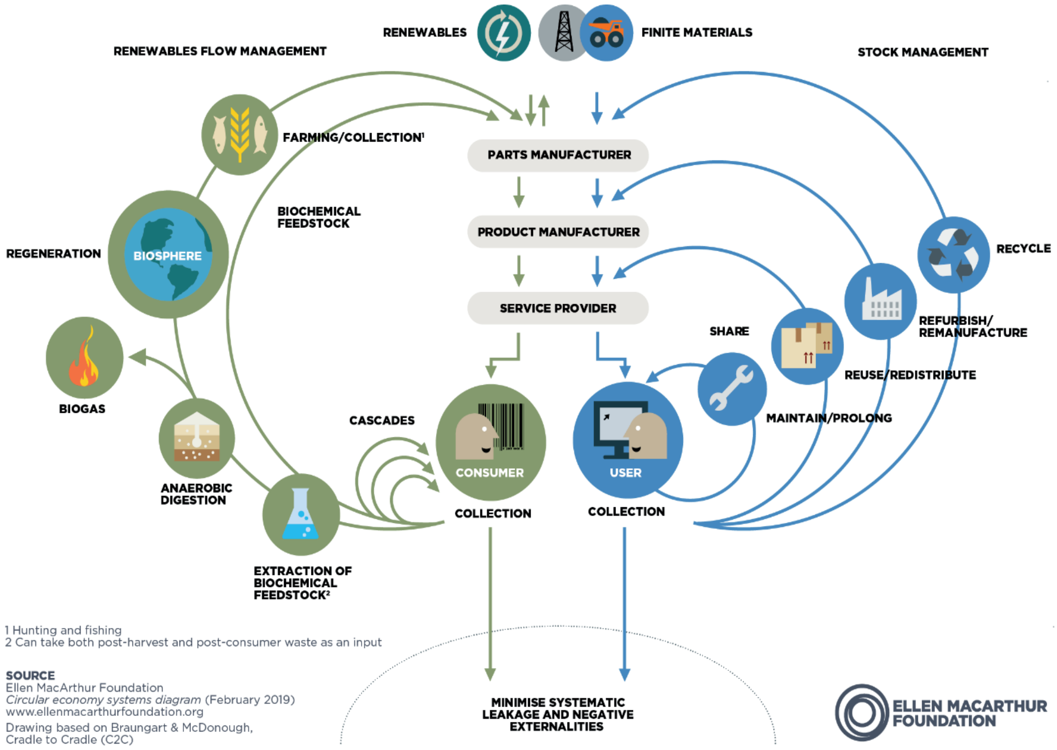

Fig. 1. Circular economy diagram (Ellen MacArthur Foundation, 2012).

Mitchell and James (2015) claim that CE prioritizes resource efficiency by maximising the value of goods and materials after their typical useful lives. However, in the CE, the final products are made to be durable, reusable, and recyclable, and resources for new products are sourced from old ones. Moreover, it aims to eliminate waste by creating products and systems that can be reused, repaired, or recycled. It moves away from the concept of a product's end-of-life and instead promotes reuse, reduction, recovery, and recycling throughout the manufacturing, transportation, and consumption processes (Kirchherr et al., 2017). Similarly, Geissdoerfer et al. (2017) characterised CE as a regeneration process that increases the consumption of raw materials while minimising emissions and waste output through repair, reusing, recycling, and refurbishing. There is acceptance that CE supports a longer lifecycle of materials, resources, and products by promoting reuse, repair, recycling, and remanufacturing. Additionally, it can be defined as an economy that is built from social production-consumption systems that maximises the benefit from the linear nature relationship with the efficiency in material and energy flow (Korhonen et al., 2018). Therefore, getting together, by closing, limiting, and reducing material and energy cycles, CE can be seen as a protection system which can reduce resource use, waste creation, leakages of the energy and emission. Furthermore, it encourages social and environmental innovation, increases resource efficiency, and promotes economic sustainability. It further promotes the creation of innovative solutions within manufacturing systems.

Depending on concern, the circular economy's fundamental principles are defined differently in various scientific studies. The five main principles – designing out waste, building resilience through diversity, depending on renewable energy, thinking about the living systems, and treating waste as food – form the core foundation of circular economy principle (Kirchherr et al., 2023). The five CE principles are related to sustainable economic performance, reduction of waste, and responsible environmental behaviours, as well as the sustainable goals. The following are the five main principles of the CE concept:

- Designing out waste: by eliminating waste, operations and the ecosystem can be improved. Designing items for deconstruction and restoration to fit into both technical and biological resource cycles aims to minimise the waste;
- Building resilience through diversity: a varied system that is built on characteristics like flexibility, adaptability, and diversity is less prone to unexpected events. Consequently, the circular economy places a high value on product diversity and high levels of adaptability to develop durable items throughout time, which could be converted into new products to ensure a recycling loop without waste (Folke et al., 2020);
- Depending on renewable energy: although there are huge amounts of energy generally during production processes, employing renewable energy sources should become the objective for industrial systems;
- Thinking about the living systems: The CE concept is influenced by living systems, where systems instead of components are improved. It is essential to understand various components of the structured technique;
- Treating waste as food: before reintroducing their nutrition into the ecosystem, technologically and biologically based resources and supplies should circulate through the economy from various applications (Ellen MacArthur Foundation, 2012).

Thinking about the living systems constitutes the most essential of the CE principles. It can be further described as "the capacity to comprehend the link between the total and the pieces, and the impact with one component upon other within a whole" (IMSA, 2013). In addition to the fundamental five principles, the 3Rs (Reduce, Reuse and Recycling) principles have been around for a while and are still highly popular today. The have been created using the "waste hierarchy" and demonstrate the specific order of importance of the steps that need to be followed to decrease the amount of waste produced as well as to enhance all other waste management procedures (Tambovceva & Titko, 2017). The 3R principles can be described as follows:

- Reduce: the major goal is to lower the volume of garbage that is produced. It is possible by beginning with a review of the products, services, and materials that are utilised, and concluding with a review of the objectives driving their utilisation;
- Reuse: the main concept would be to reuse anything and everything as often as can before substituting it. Even things that someone would like to discard can be made into something valuable;
- Recycle: recycling (composting) is carried out to ensure that products or their parts are as often placed to a new use as possible. To recycle something is to reprocess it into raw resources which can be utilised to create a new product (Tambovceva & Titko, 2017).

In addition to the traditional 3R principles, the framework has been expanded to include the 4R model by adding “rethink” or “recovery.” It has since evolved into the 5R principles: Refuse, Reduce, Reuse, Recycle, and Recover (Tan et al., 2016), followed by the 6R model: Rethink, Reduce, Refuse, Repair, Recycle, and Rebuy, and later followed by the 7R system: Refuse, Reduce, Reuse, Recover, Repair, Recycle, and Regift (Van Ree, 2016; Tambovceva & Titko, 2017). The 9R principles aim to explain how the linear economy transitions towards CE. The 9R model is the final established concept. In CE, “refuse” is described at the highest levels of use (Kirchherr et al., 2023). It indicates that the products are now being replaced by something entirely different or that they are no longer required or helpful. The linear economics and “recovery” are described at the lowest level. On this level, garbage is burned, producing energy as well as heat to later use.

1.2. Characteristics of Sustainable Buildings

Buildings are the main source of energy usage and emissions of carbon dioxide (CO_2) in many countries. For instance, building construction and operation play an important role in this process because they are contributing to 37 % of the world’s CO_2 emissions related to energy and 40 % of the consumption of energy in the EU (European Commission, 2020). Consequently, in developing nations where significant economic growth is correlated with a booming construction sector, energy use and building-related greenhouse gas emissions are increasing rapidly as urbanisation and industrialisation intensify. Hence, a sizable number of new structures are constructed each year in many emerging nations. When considering environmental effects, the construction sector significantly contributes to environmental degradation, responsible for roughly 23 % of air pollution, 50 % of climate change effects, 40 % of drinking water contamination, and 50 % of landfill waste (Ira, 2021). Furthermore, global GHG emissions from buildings are expected to reach 15 billion CO_2 by 2030, with Asian countries accounting for nearly 1/3 of these emissions (European Commission, 2023).

The idea of sustainable building predates the formal definition of sustainability, originating in the early twentieth century when diverse communities promoted green architecture, motivated by the desire for an ecologically conscious world. In addition, the energy crisis resulted in the support of regulations limiting how much energy buildings can use. As a result, sustainability adopted energy consumption as a unit of measurement for sustainable buildings. In this way, to construct buildings that are pleasant and comfortable, sanitary, secure, and productive, sustainable building primarily aims to develop “eco-friendly construction procedures” that reduce waste of raw materials, energy, water, as well as greenhouse gas emissions for addressing the issues of linear economic system (Neyestani, 2017). Therefore, a sustainable building is referred to as a “green building” or an “environmentally sound” building that addresses the circularity in the construction industry. Some refer to it as “timeless”, while others call sustainable structures “smart buildings” or buildings with advanced technologies. Sustainable building is formed taking into the aspects of materials balance models with interactions between both the economy and the environment. Furthermore, buildings that are more ecologically friendly throughout their full life cycle (from site selection to demolition phase) are referred to as sustainable buildings (Neyestani, 2017).

According to the conceptualisation of sustainable building with economy and the environment (see Fig. 2), the “economic system” is “open” and “circular,” defined by several “processes for extracting mass and energy out from environment,” followed by primary procedures of processing, producing, and consumption. At the conclusion of each of these processes, waste is no longer usable in the environment or in the contact bodies. Additionally, all the manufacturing, activities, and consumption levels are centred on building sustainability within the goal of creating a profitable building with the least amount of environmental harm (Neyestani, 2017).

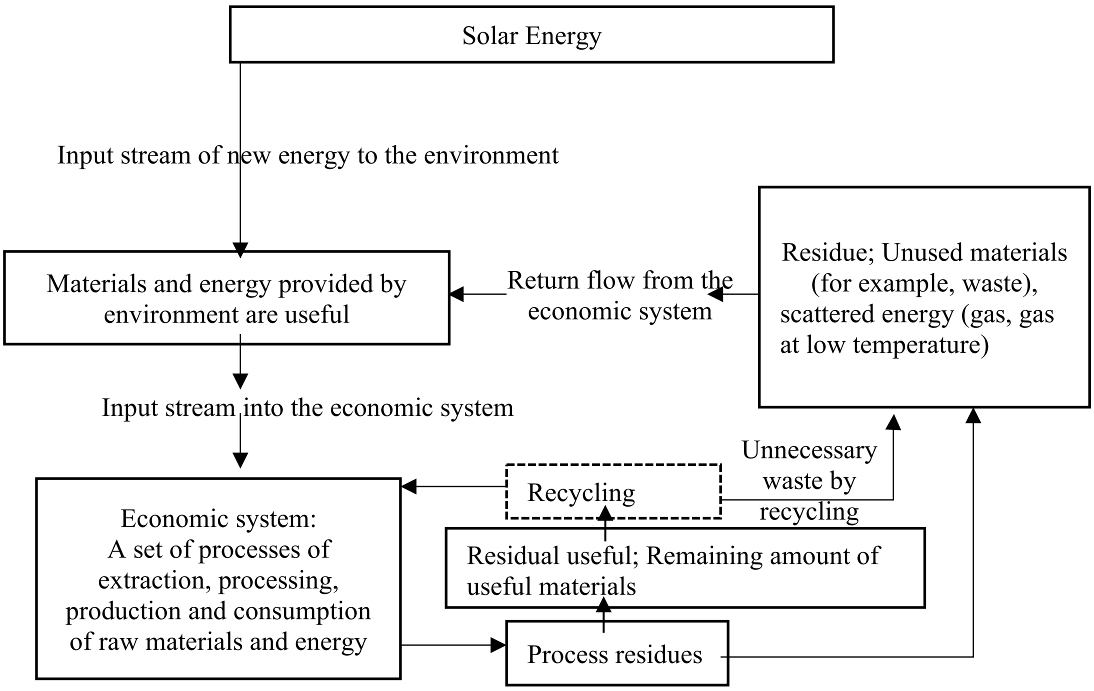

Fig. 2. Relationship of sustainable building with economy and the environment (developed by the authors based on Neyestani, 2017).

Consequently, it is important to constantly adopt innovative green building technologies to reduce the amount of electricity consumed by the structure and the negative effects it has on the environment. Therefore, the major characteristics of sustainable buildings in the construction industry can be emphasised as follows (International Telecommunication Union, 2013): improving and preserving the well-being as well as health of the residents, using resources (such as water and energy) more effectively, minimising negative effects such as pollution, waste, and sewage. Throughout every stage of their life cycle, sustainable buildings maximise each of these characteristics. Using sustainable (green) technology, which is more involved in the creation and use of goods, tools, and processes that protect the environment, and its resources is essential to the construction of sustainable (green) buildings. Such technologies could greatly improve a building's performance in terms of economic efficiency, environmental sustainability, and occupant well-being. A variety of equipment and instruments can be used in the construction sector to promote sustainable building practices. The resources can be methodically divided into four main domains:

- Energy: heat pumps, and renewable power (solar energy);
- Water technology: water harvesting and waterway systems;
- Light: energy-efficient light bulbs, CFL bulbs system, LEDs, sustainable lighting;
- Natural lighting system and natural ventilation (International Telecommunication Union, 2013).

Furthermore, sustainable buildings provide greater advantages for the society, environment, and the economy of every nation. The reduction of energy and water costs is without a doubt the biggest advantage of sustainable building (Yun, 2014). According to a study of 99 sustainable buildings in the USA, they use 30 % less energy on average than conventional buildings (Ravasio et al., 2020). The built environment, including buildings, has a significant effect on nature. It is interesting to note that sustainable buildings have the capacity to lessen their adverse environmental impacts while providing advantages for industry and inhabitant health. Compared to conventional structures, sustainable buildings use resources like energy, water, and land more wisely while also creating less contamination and waste (Neyestani, 2017). Sustainable buildings frequently incorporate recycled materials as well as relatively low or non-toxic materials. Moreover, the social motivation to develop sustainable building today, especially in large cities, is the "feel-good" aspect. The social advantages of sustainable building design are more closely linked to enhancements in health, quality of life and social well-being. Strong sustainable structures have a good impact on society as well as on people (Neyestani, 2017). Because they offer superior quality of indoor air, comfort, and efficiency, sustainable buildings are also more likely to convince consumers that they will have a beneficial effect on their well-being and happiness.

1.3. Overview of Sustainable Construction

Heavy reliance on natural resources, the material, liquid, and air pollutants produced at the completion of building and demolition projects as a result of the construction industry's activities have a significant detrimental influence on the natural environment. Use of non-renewable resources, a decline in biodiversity, the loss of agricultural lands, pollution of soil, gas, and water, the degradation of natural green spaces, and climate change can be summed up as these adverse effects from the current linear economic systems. Sustainable construction is a sub-section of sustainable development, used to describe how the clients, manufacturers, users, (Shen et al., 2010) and suppliers have applied sustainable development elements to the construction industry for addressing the economic, ecological and social issues of a constructing in the sense of its society, as well as the contribution of the built-up edge to the overall goal of sustainable development (Kibert, 2013).

The term's original formal definition, provided by the CIB in 1994, described sustainable construction as the creation and maintenance of a built environment centered on resource efficiency and ecological principles. Moreover, sustainable construction is the implementation of the concepts of sustainable development to the planning, design, production, and use of building materials as well as the disposal of waste generated during the construction process. It is a comprehensive process that strives to preserve balance between the natural and built environments by developing communities that are friendly to people and promote economic equality (Yilmaz & Adem, 2015). Consequently, the concept of sustainable construction continues long after the construction project is over; the building's structure should have little effect on the environment over the building's lifespan. It implies that the building's construction should include components and materials, which continuously affect how the structure affects the environment.

The main principles of sustainable construction can be elaborated as follows (Shen et al., 2010):

- Resource reusage maximisation (Reuse);
- Usage of renewable and recyclable resources (Renew/Recycle);
- Construction of non-toxic and healthy environment (Non-toxic);
- Resource consumption minimisation (Conserve);
- Protecting the natural environment (Protect nature);
- Creation of quality in-built environment (Quality) (Shen et al., 2010; Akadiri et al., 2012).

These six principles of construction products needed to be maximised towards enhancing the sustainability performance, considering the factors such as weather, society, advancement of industrial development etc.:

- Reuse: reusing components are simply used after the minimal reprocessing procedures. Therefore, the reusing of some construction materials such as windows, bricks as well as doors for the reconstruction or the new construction will be profitable for the owners and the architecture as well (Shen et al., 2010).
- Recycle: while using resources in construction, it is imperative to give recyclable, or renewable resource. When using renewable energy sources like solar and wind energy, this principle is applicable. It needs to apply to substances like wood. This popular building material could be acquired from sustainably managed forests, giving the purchaser some degree of confidence that the providers are conserving the environment while maintaining their resources (Citraningrum et al., 2023).
- Non-toxic: one strategy is to think about completely getting rid of toxic materials from the construction process unless the producers could

maintain them in such a closed loop system. Most of the developed countries are starting to investigate the establishment of reversed distribution, a process in which products are returned to the producer for the recovery of harmful ingredients for recycling into other new products (Shen et al., 2010; Küpfer et al., 2023).

- Conserve: while reducing energy consumption is crucial, it encourages to employ passive techniques to supply heating, ventilation, lighting and cooling for the constructed buildings. It forces to think about high-performing windows, massive amounts of insulation, low flow fixtures, and efficient systems. It also encourages the adoption of strength and durability with extended lifespans and minimal maintenance requirements (Küpfer et al., 2023).
- Protect nature: the recent harm done to the environment through the unsustainable construction based on the linear economic system, possibly it is now more important than ever to "restore" where it is feasible rather than just "sustain". By making thoughtful adjustments to the construction in the future, the excesses of river straighten, marsh drained, and deforestation could be corrected to protect nature.
- Quality: the idea of quality as an element of sustainable construction is crucial, while being frequently mentioned and equally frequently misused. It involves the development of communities to cut down on car trips, boost social interaction, and offer a high standard of living. The decisions, including material selection, energy system design, smart lighting design, including designing of passive energy systems, are predicated on the notion that are necessary for increasing the quality of the sustainable construction (Citraningrum et al., 2023).

2. METHODS AND PROCEDURES

The study is designed to evaluate the current situation of CE principle application for sustainable building performance of the construction industry in Sri Lanka and provide recommendations to develop circular economy strategies for the improvement of the sustainable building performance in the construction industry of Sri Lanka.

2.1. Data Collection Procedure

To achieve the intended outcomes of the study, both primary and secondary data were used in the study. Primary data were collected from the questionnaire survey which was targeting the Sri Lankan construction industry professionals' perceptions to evaluate the current situation of application of CE principles to the sustainable building performance of the construction industry in Sri Lanka. Numerous studies related to the applicability of CE for the construction industry have verified the suitability of questionnaire survey methods for getting the experts' perceptions and opinions (Wanaguru et al., 2022; Nawarathna et al., 2022). The questionnaire with the question types of open-ended, closed-ended and 5-point

Likert scale was helpful in gaining a thorough understanding of the perspectives of all relevant professionals. Secondary data were utilised to conceptualise the study's background through an examination of CE and sustainability concepts, characteristics, and principles. The data were obtained from reputable scholarly databases, including Google Scholar, Scopus, and ScienceDirect. Previous literature sources were filtered out with the key words "circular economy", "sustainable building", "construction industry" and "sustainable construction". Gathering secondary data was targeted to enrich the results gained from the questionnaire survey.

2.2. Sample Selection

The targeted population for the distribution of the questionnaire was determined to be construction professionals with knowledge, experience, and expertise in the construction industry of Sri Lanka. According to Creswell (2014), an appropriate study sample is crucial to accurately represent the complete population. The absence of a comprehensive list of the study population prohibited the use of a probability sampling technique in this investigation. Instead, convenience sampling, a non-probability sampling approach, was used. Instead of selecting randomly from the entire population within the limited data-collection timeframe, the study took advantage of a group of easily accessible construction industry professionals who were representative of the target population. The target respondents of the study included engineers, project managers, architects, quantity surveyors, and site supervisors of the construction industry of Sri Lanka. The questionnaire was distributed to the construction professionals identified through the established contacts. The sample size was further increased by asking the respondents to disseminate the questionnaire to all pertinent professionals in their network. Due to the authors' concerns with staying a long distance, an online questionnaire survey was conducted utilising Google Forms for all respondents. The questionnaire was distributed among 80 construction industry professionals in Sri Lanka, and 57 responses were returned as an overall responses rate of 71.25 % due to the limited time allocated for data collection. Accordingly, the acceptable response rate for the social research surveys is 50 % (Wanaguru et al., 2022). Therefore, the overall response rate of the research study (71.25 %) was at the acceptable level.

2.3. Data Analysis Procedure

The collected data were analysed using quantitative methods, specifically descriptive statistical techniques, including frequency analysis, mean comparison, and standard deviation. Moreover, the authors employed Pearson correlation analysis for measuring the causal relationships of variables for one to another. These analyses were performed using Statistical Package for the Social Sciences (SPSS). Moreover, pie charts and bar graphs were utilised to assess the percentage of each response that survey respondents chose for each question using a frequency distribution approach.

3. RESULTS AND DISCUSSION

3.1. Demographic Characteristics of the Respondents

A questionnaire survey was conducted to evaluate the current situation of CE principle application to the sustainable building performance of the construction industry in Sri Lanka through the construction professionals' perspectives. The demographic details immediately demonstrated the accuracy and authenticity of the data collected to produce the intended survey results based on the 57 responses received out of 80. The authors ranked project managers, engineers, architects, quantity surveyors, and site supervisors as the top 5 most valuable specialists in the Sri Lankan construction industry (see Fig. 3). The respondents were also provided with an additional option to indicate involvement in construction-related professions other than those specified in the predefined list.

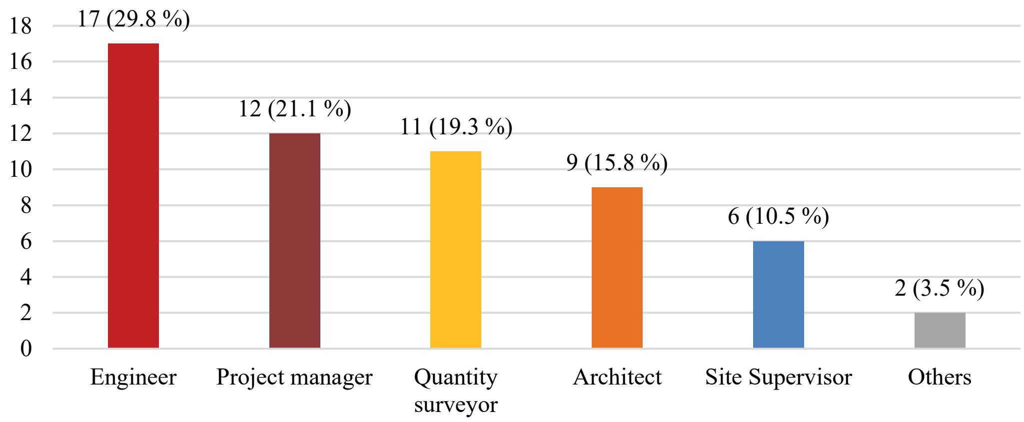

Fig. 3. The number of respondents in the study by profession (developed by the authors).

According to Fig. 3, engineering professionals, such as civil and building system engineers, provided the most responses, which were 17 (29.8 %), while other professions, including development assistants and facility managers, provided the least number of responses, i.e., 2 (3.5 %). Project managers, quantity surveyors, and architects accounted for 12 responses (21.1 %), 11 responses (19.3 %), and 9 responses (15.8 %) of the total, respectively, while site supervisors contributed to 6 responses (10.5 %). Each professional group's input was distinct and played a critical role in ensuring the accuracy and comprehensiveness of the survey findings.

The participants' working experience in the construction sector of Sri Lanka serves as an illustration of an additional demographic feature. In the Sri Lankan construction sector, professionals with different levels of expertise can be divided into experts and non-experts. Therefore, professionals with 4–6 years, 6–10 years, and more than 10 years of work experience in the construction industry are regarded as experts in the field, while others are considered as non-experts (see Fig. 4).

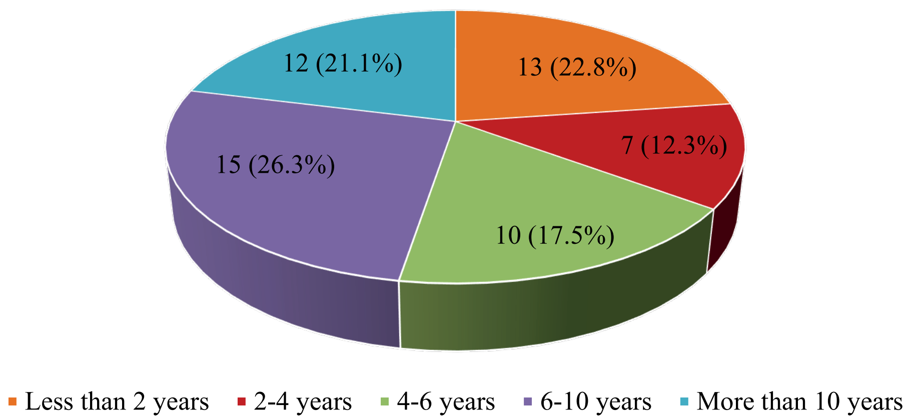

Fig. 4. The response ratio based on the respondents' work experience (developed by the authors).

As shown by the results, 26.3 % of respondents who provided the highest responses rate have 6–10 years of the work experience in the Sri Lankan construction industry. Professionals with less than 2 years of the work experience provided the second-highest percentage of responses (22.8 % of all responses). Additionally, professionals with more than 10 years of the work experience represent 21.1 % of the professionals, while those with 4–6 years of the work experience represent 17.5 %. Professionals with 2–4 years of the work experience in the Sri Lankan construction sector provided the lowest number of responses (12.3 %). As a result, professionals in the construction sector with more than 4 years of experience comprise 64.9 % of the total number of the respondents. Only 35.1 % of respondents who have less than 4 years of work experience were regarded as non-experts in the field. The results indicate that the respondents' expertise in the construction sector ranged from the non-expert to expert level, thereby contributing to the provision of more accurate and reliable data for the research outcomes.

3.2. Assessment of Circular Economy Principles for the Construction Industry

Understanding the importance of CE for the Sri Lankan construction industry is just as essential as noting the professionals' perspectives, even if they are already familiar with the concept. The adoption of the CE concept in the construction industry is essential; without it, efforts toward sustainability will be ineffective. Accordingly, based on 5-point Likert scale, answer "1" is strongly disagree, "2" – disagree, "3" – neutral, "4" – agree and "5" – strongly agree. Based on the SPSS statistical software, the findings of the frequency distribution are shown in Table 1.

According to the results, 40.4 % of respondents agreed that the circular economy is important for the Sri Lankan construction industry. Only 1.8 % expressed their disagreement with the statement. Additionally, 21 professionals, or 36.8 %, had the perception of strongly agreeing, while 21.1 % had a neutral opinion. Furthermore, none of the respondents strongly disagreed with the importance of the circular economy concept for Sri Lanka's construction industry. As per the results, implementing the CE concept is crucial for the Sri Lankan construction industry to attain sustainability.

Table 1. Frequency Analysis of Responses regarding the Importance of Circular Economy for the Construction Industry of Sri Lanka (developed by the authors)

Frequency Analysis				
		Frequency	Valid percent	Cumulative percent
Importance of circular economy for the construction industry of Sri Lanka	Strongly Disagree	0	0	0
	Disagree	1	1.8	1.8
	Neutral	12	21.1	22.8
	Agree	23	40.4	63.2
	Strongly agree	21	36.8	100.0
	Total	57	100.0	

This paragraph provides insight into the current state of circular economy principle applicability within the Sri Lankan construction industry. Respondents' perceptions were captured using a five-point Likert scale, with response options aligned to each circular economy principle identified through the comprehensive literature review. The authors have mentioned five principles introduced by Ellen MacArthur Foundation (2012): designing out waste, increasing resilience by diversity, developing renewable energy, systems thinking and treating waste as a resource. Respondents selected from a five-point scale, where "1" indicated very low, "2" low, "3" moderate, "4" high, and "5" very high. Table 2 provides the interpretation of the respondents' choices using the descriptive statistical mean and standard deviation analysis (see Table 2).

Table 2. Descriptive Statistical Findings about the Extent of Applicability of Circular Economy Principles to the Sri Lankan Construction Industry (developed by the authors)

Descriptive Statistics			
	N	Mean	Std. Deviation
1. Designing out waste	57	2.60	0.704
2. Increasing the resilience by diversity (adaptability to develop durable items)	57	2.42	0.801
3. Developing renewable energy	57	2.35	0.767
4. Systems thinking (capacity to interact as a whole not as a single component)	57	2.25	1.005
5. Treating waste as a resource (waste can be recycled and reused)	57	2.56	0.846
Valid *N* (listwise)	57		

The descriptive statistical analysis indicates the mean value and the standard deviation of the responses. The standard deviation is a measure of the statistical dispersion of the total responses of each principle relative to the mean values. The mean value is the average number of responses for every rating provided by respondents. The responses are better and dependable when the standard deviation has a lower value. Consequently, the principle of designing out waste has the highest mean value (2.60), and its standard deviation is the lowest one (0.704), compared to other principles. This shows that, when compared to the other four principles, the concept of designing out waste has the highest level of application to the Sri Lankan building industry. Systems thinking has the lowest level of mean value (2.25) and the highest standard deviation of 1.005 since the principle is not currently utilised in the construction sector in Sri Lanka. The principle of treating waste as a resource has a mean value of 2.56, placing it as the second most feasible to Sri Lanka's building industry among the other principles taken into consideration in the study. The principles of increasing resilience and developing renewable energy sources have respective mean values of 2.42 and 2.35, respectively. These two principles have a moderate level of application to Sri Lanka's construction industry. However, as the findings indicate that each of the five principles is applied to a low to moderate extent, the development of these principles holds significance, particularly through the introduction of innovative circular economy approaches within the Sri Lankan construction industry.

The frequency analysis (see Table 3) outlines the overall satisfaction level of respondents with the degree of applicability of the CE concept and application utilised by Sri Lanka's construction industry. It is important to understand their general contentment with the CE applications in the current scenario before offering solutions. If the respondents are dissatisfied with the current applicability, the authors might develop solutions to meet their demands and requirements. It indicates the general state of the CE applicability to the construction sector and is, therefore, one of the most crucial ones. Furthermore, as these individuals hold primary responsibility within the sector and possess extensive knowledge, examining the issue from the perspectives of professionals using a top-down approach yields more credible findings.

In accordance with the frequency analysis findings, 47.4 % of the respondents were dissatisfied with the way the circular economy was applied to the construction sector. Among the other replies, the "neutral" category had the second-highest response rate with 31.6 %. Only 15.8 % of respondents were very dissatisfied with the way the circular economy was applied to the Sri Lankan construction industry. While just 1.8 % of responses indicated that they were "very satisfied" in every aspect of CE applicability. In contrast, the mean value of the responses was 2.3, which indicated that most respondents were dissatisfied with the level of applicability of CE principles to the Sri Lankan construction industry.

The authors also aimed to examine the relationship between the perceived degree of application of CE principles to the construction industry and the overall level of satisfaction with each principle, as relevant to the current context of Sri Lanka's construction sector. Hence, the authors used the Pearson correlation analysis, which can be performed with the SPSS statistical package to quantify the relationship between variables in a reliable manner. The "*r*" value (correlation co-efficient), which can be positive or negative, indicates the strength of the connection between variables taken into considerations. Values are required to lie within the range of −1 to +1. Positive (+) value shows a positive relationship, and negative (−) value shows the negative relationship. The probability that the reported results are true and can be accepted statistically is represented by "*p*" in the significance value. The authors are considered when the p-value ≤ 0.05 level, which shows the significance of the data that was illustrated (see Table 4).

Table 3. Frequency Analysis of the Overall Satisfaction regarding the Level of Applicability of the Circular Economy to the Construction Industry in Sri Lanka (developed by the authors)

Frequency Analysis				
		Frequency	Valid Percent	Cumulative Percent
Overall satisfaction regarding the level of applicability of the circular economy to the construction industry in Sri Lanka	Very unsatisfied	9	15.8	15.8
	Unsatisfied	27	47.4	63.2
	Neutral	18	31.6	94.7
	Satisfied	2	3.5	98.2
	Very satisfied	1	1.8	100.0
	Total	57	100.0	

The results indicate a significant positive relationship, at the 0.05 level, between overall satisfaction and the degree of applicability of the five circular economy principles in the Sri Lankan construction industry. This finding suggests that broader implementation of these principles within the sector is likely to enhance respondents' overall satisfaction levels. On the contrary, the lack of applicability of circular economy concepts led to a rise in respondents' dissatisfaction. The highest positive relationship ($r = 0.379$*, $p = 0.004$) can be seen from increasing the resilience by diversity with the overall satisfaction regarding circular economy applicability. Respectively, systems thinking ($r = 0.319$*, $p = 0.016$), developing renewable energy ($r = 0.122$*, $p = 0.037$), treating waste as a resource ($r = 0.076$*, $p = 0.057$) and designing out waste ($r = 0.016$*, $p = 0.034$) all demonstrate positive correlations. All variables exhibit a significant positive relationship, highlighting the need to enhance the application of the five circular economy principles within the Sri Lankan construction industry to promote sustainability. Consequently, this is expected to improve the satisfaction levels of the construction industry professionals in their efforts toward achieving sustainable construction practices.

In terms of sustainability, it is necessary to determine what should be improved to achieve the sustainable construction industry in Sri Lanka. It is necessary to understand the construction industry's sustainable performance through the main principles of sustainable construction (see Fig. 5). As a result, this inquiry is valuable in formulating recommendations of the study.

Table 4. Pearson Correlation Coefficient Analysis Results for the Extent of Circular Economy Principle Applicability into the Construction Industry and the Overall Satisfaction Level of Respondents regarding the Circular Economy Concept (developed by the authors)

Correlation Analysis							
		Designing Out waste	Increasing the resilience by diversity (adaptability to develop durable items)	Developing renewable energy	Systems thinking (capacity to interact as a whole not as a single component)	Treating waste as a resource (waste can be recycled and reused)
Overall satisfaction regarding the level of applicability of the circular economy principles to the construction industry in Sri Lanka	Pearson correlation	0.016*	0.379*	0.122*	0.319*	0.076*
	Sig. (2-tailed)	0.034	0.004	0.037	0.016	0.057
	N	57	57	57	57	57
* Correlation is significant at the 0.05 level (2-tailed).						

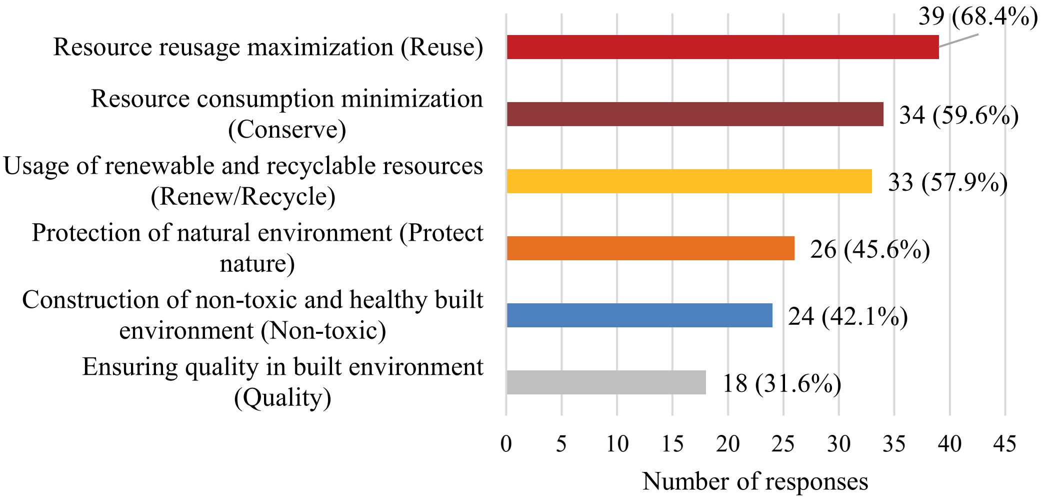

Fig. 5. Responses of principles that need to be maximised to enhance the sustainability performance of the Sri Lankan construction industry (developed by the authors).

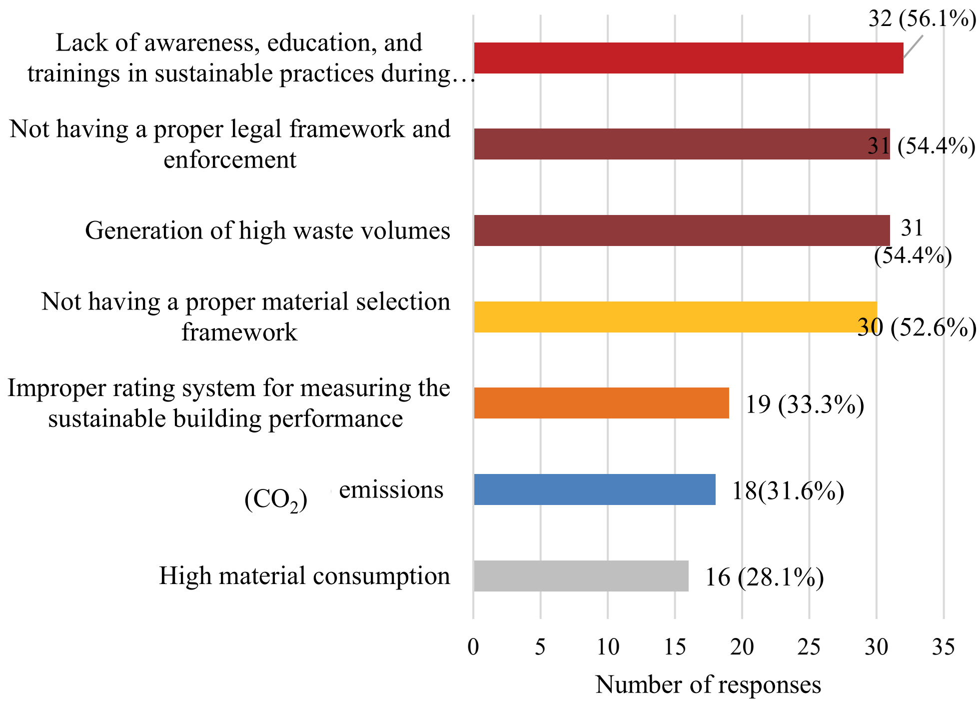

Fig. 6. Responses of prevailing problems in the Sri Lankan construction industry (developed by the authors).

Based on the findings, resource reusage maximisation (Reuse) is indicated as the highest responded sustainable principle that needs to be improved in the construction industry to achieve sustainability. It shows that among total responses, 39 professionals (68.4 %) have responded that the reuse principle will be profitable for the investors and professionals. The principle of ensuring quality in the built environment (Quality) received the fewest responses, with 18 responses (31.6 %). The second most frequently cited factor for achieving sustainability in the construction sector is resource consumption minimisation (Conserve), which received 34 responses (59.6 %), emphasising the importance of strength, durability, and extended lifespans. The use of renewable and recyclable resources (Renew/Recycle) received 33 responses (57.9 %), protection of the natural environment (Protect Nature) received 26 responses (45.6 %), and the construction of non-toxic and healthy built environments received 24 responses (42.1 %). To promote a sustainable building industry in Sri Lanka, the principles of reuse and conservation should be prioritized within construction practices.

Furthermore, it is useful to identify current problems from a professional's perspective to develop strategies for solving them and maintaining the items that are functioning properly. The authors have provided multiple answer options for the respondents to obtain their detailed thoughts on the problems facing the Sri Lankan construction industry (see Fig. 6).

The major issues in the existing situation in the Sri Lankan construction industry is a lack of awareness, education and training in the sustainable practices during the construction projects, which indicated 32 responses with a 56.1 % response rate. It is the main root cause of the occurrence of other issues in the construction industry. The construction industry, along with the wider society, demonstrates a limited level of awareness regarding the application of circular economy principles for achieving sustainability in construction. When awareness levels are low, decision-makers tend to prioritize conventional cost-reduction measures, avoid the adoption of innovative technologies, and remain largely uninformed about sustainable construction practices and relevant capacity-building initiatives. This lack of awareness hinders the integration of environmentally responsible strategies and impedes the transition towards a more sustainable construction sector. Additionally, it encourages disregard for environmentally favourable methods and continuous environmental harm. The absence of an adequate legal framework and enforcement mechanisms, along with the generation of high volumes of waste, received similar levels of concern, with 31 respondents (54.4 %) identifying these as critical challenges. This represents the second-highest response rate among all categories, indicating that both factors are perceived as significant and pressing issues currently affecting the construction industry. Blue-Green guidelines are designed for only the new constructions and not regarding the already constructed buildings. Therefore, it is necessary to strengthen the legal framework. Waste generation is one of the significant issues in construction. Additionally, some waste types, notably hazardous waste like glass wool, cannot be disposed of in a proper manner. Not having proper material selection framework was identified in 30 responses, representing 52.6 % of the total responses. From the professional's perception, the improper rating system for measuring sustainable building performance represents 19 responses (33.3 %) and carbon dioxide emissions are represented by 18 responses (31.6 %). High material consumption in the building sector, which is only represented by 28.1 % (16 responses), is the issue that occurs the least frequently among all the others. Circular economy strategies are capable of being used to address these problems and provide a sustainable future for the building industry of Sri Lanka.

A critical consideration is the extent to which the fundamental strategies of the circular economy can be leveraged to mitigate the previously identified issues. According to professionals, high waste production, an inadequate legal system, and carbon dioxide emissions are the most frequent problems in the construction industry. The authors identified some issues and gave the respondents a chance to provide their choices accordingly. The mean and standard deviation analyses based on descriptive statistical methods were utilised to interpret the findings (see Table 5).

Table 5. Descriptive Statistical Results of Importance of Circular Economy Principles in Tackling the Problems of the Sri Lankan Construction Industry to Achieve Sustainability (developed by the authors)

Descriptive Statistics			
	N	Mean	Std. Deviation
High material consumption	57	3.23	1.337
High volume of waste generation	57	3.61	1.292
Pollution (water and land)	57	3.53	1.283
Carbon dioxide emissions	57	3.33	1.185
Improper material selection	57	3.37	1.234
Climate change	57	3.26	1.357
Impact on the human health	57	3.34	1.225
Valid *N* (listwise)	57		

According to the descriptive statistics, the responses' mean value and standard deviation indicate the importance of the circular economy principles for tackling the existing issues of the construction industry. Circular economy principles are considered highly significant in addressing the prevailing issue of high-volume waste generation, as reflected by a mean score of 3.61 and a relatively low standard deviation of 1.292. The problem of water and land pollution, which needs to be handled using the circular economic principles, has the second-highest mean value (3.53). The findings indicate that high material consumption received the lowest level of importance in relation to being addressed through circular economy principles, with a mean value of 3.23. This suggests that, within the context of the Sri Lankan construction industry, high material consumption is not perceived as a critical issue. Similarly, the problem of climate change is also considered to be of comparatively low relevance to CE implementation, as reflected by a mean value of 3.26. These results highlight that, from the respondents' perspective, certain environmental and sustainability-related concerns are not strongly associated with the potential benefits of adopting circular economic approaches in the industry. "Improper material selection" and "impact on the human health" have shown mean values of 3.37 and 3.34, respectively. Considering the overall set of mean values, the results suggest that the applicability of circular economy principles is significant for addressing the range of prevailing challenges in the Sri Lankan construction sector. Therefore, to effectively mitigate these issues, the development and implementation of innovative CE strategies are essential.

CONCLUSIONS

The construction industry is an important industry that affects the nation's economy and ecology. The necessity of the construction industry is now widely acknowledged, and both industrialised and developing nations are aware of its significance for the economy's sustainable growth. However, many emerging nations, including Sri Lanka, achieve lower levels of compliance with circular economy principles and practices. Moreover, there is a claim that the Sri Lankan construction industry is only just beginning to acknowledge circularity principles (Wijewansha et al., 2020). Therefore, the research aim was to evaluate the current situation of CE principle application for the sustainable building performance of the construction industry in Sri Lanka and provide recommendations to develop CE strategies for the improvement of the sustainable building performance in the Sri Lankan construction industry.

Based on the results of the survey, the circular economy principles are applied in the construction industry at a lower level throughout the whole construction lifecycle process. According to the data, there is a strong positive correlation between the overall satisfaction of construction industry professionals and the capacity of the construction industry to apply circular economic principles. Lack of awareness, education, and training in sustainable practices during the construction projects, not having a proper legal framework and enforcement, generation of high waste volumes and carbon dioxide emissions are the most prevailing issues in the construction sector due to the linear economy pattern, based on the survey results.

Based on the findings, it is recommended that the adoption of green building practices be actively promoted within the Sri Lankan construction industry to advance the nation towards a sustainable construction future. These practices integrate environmental considerations, health and well-being factors, and occupant comfort into the design, construction, and management of buildings. Green building technologies are positively influencing the environment and utilising the resources effectively during a building's lifespan. Consequently, in Sri Lanka, the construction process increasingly incorporates advanced energy-efficient technologies and practices across all building components, from the foundation to the roofing, to enhance overall building sustainability. Every relevant organisation in the Sri Lankan construction sector must be concerned about the use of locally sourced eco-friendly building materials during the construction of buildings to minimise construction costs and increase profitability. Moreover, the Sri Lankan government and construction regulatory authorities should educate the society through social media and other online platforms about the negative effects of the construction industry and how they can be mitigated through the application of circular economy principles. Finally, it can serve as the foundation for a bottom-up approach to achieve a sustainable construction industry in Sri Lanka.

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