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ASSESSMENT OF IMPLEMENTATION OF CIRCULAR ECONOMY FRAMEWORK IN THE SRI LANKAN CONSTRUCTION SECTOR

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Abstract. Concerns have been raised that the construction sector in both developed and developing countries has become a major environmental issue. This is mostly due to the excessive use of raw materials and energy sources. Moreover, the industry now follows the "take-make-dispose" linear economic paradigm. The circular economy idea was just brought to the sector based on the fundamental principles "reduce, reuse, recycle", and yet the construction industry in Sri Lanka has failed to comply with this emerging framework. It is presently being debated throughout the world whether the 3R concept is adequate to achieve optimal industry sustainability. As a result, the 3R principles have lately expanded into a 10R framework. Consequently, the purpose of this article is to determine the possibilities and barriers to implement the 10R framework in the construction sector in Sri Lanka. The study was conducted using a qualitative research method. A semi-structured questionnaire was used to gather data and gain expert opinions on various options. This research takes a qualitative, in-depth look at how the 10R principles of circular economy might be applied to construction projects. Construction professionals may boost the ecological sustainability of building projects by using the recommended circular economy guidelines.

Keywords: *barriers, circular economy, construction, Sri Lanka, sustainability, 10R principles.*

INTRODUCTION

Construction is a highly complex, dynamic, and diverse industry that includes the design and construction of new buildings and engineering projects, as well as the rehabilitation and upgrade of existing ones (Çelik et al., 2017). Furthermore, it has been known for almost three decades that the building sector consumes a substantial quantity of natural resources, since it was responsible for more than 40 % in the 1990s and presently accounts for roughly 30 % (Benachio et al., 2020). Furthermore, it generates more than three billion tons of waste from construction and demolition (C&D) each year (Akhtar & Sarmah, 2018). Construction waste is one of the most significant waste streams worldwide and has been highlighted as a major issue in the construction industry (Spišáková et al., 2021). It has become a serious environmental problem in both economically developed and developing countries (Mohammed et al., 2022). If this condition continues, a variety of material resources will become expensive, scarce, and maybe even extinct for future generations to use (DEFRA, 2012).

To address these concerns, the circular economy (CE) concept was introduced, which is based on the essential notions of cradle-to-cradle material circulation, reuse, recycling, and remanufacturing in a closed-loop system for social and technological growth (Adabre et al., 2023). The goal of the CE is to lead to a more sustainable economy, contributing to recycling and reuse of products, and, consequently, to make them "circular" (Zvirgzdins et al., 2020). CE can contribute to resolving such global issues as climate change, deforestation, resource depletion, urbanization, pollution, and others (Zvirgzdins et al., 2019). On top of that, benefits of circular economy go beyond the national borders (Zvirgzdins et al., 2018). Resource-efficient building is a prominent subject across the world, especially since the CE idea has lately developed at multiple levels, including governments, enterprises, and academics. This is due to escalating building material demand, restricted material supply, and rising ecological disasters (Reike et al., 2018). This is tied to the underlying need and desire for a growth paradigm other than the established take-make-dispose linear economy (Lieder & Rashid, 2016). Building materials that have reached the end of their useful life, according to the CE model, should be reused and their parts and components deconstructed to serve as material banks for new buildings, therefore maintaining the parts and materials in a closed loop (Hopkinson et al., 2019). Additionally, this concept has origins in regenerative design, ecological and environmental economics, the 3R principles (reduce, reuse, recycle), blue economy, cradle-to-cradle approach, industrial symbiosis, performance economy, green growth, biomimicry, and similar concepts (Ghisellini et al., 2016).

Sri Lanka's building sector has grown significantly during the last 10 years. Sri Lanka is also being more afflicted by environmental issues caused by unsustainable development practices (Athapaththu et al., 2016). One of these problems was the lack of design decision-making in the Sri Lankan construction sector for implementing low embodied and operational energy solutions in buildings. Improving sustainability in the Sri Lankan construction sector is a subject that requires greater attention and focus (Liyanage et al., 2019). As a result, it is critical to promote sustainability in Sri Lankan construction techniques. As a result of increased interest in its supposed benefits, there has been a surge in the amount of literature on CE adoption. Some have focused on measures for monitoring CE's current development, while others have focused on drivers, endangerments, and barriers (Adabre et al., 2022). Sri Lanka must make a tremendous effort to meet international standards for sustainable building. The scarcity of publications in this field indicates that the Sri Lankan construction business is fairly new to sustainability-based notions like CE (Wijewansha et al., 2021).

Within the study the following objectives have been set:

- to assess potential strategies and drivers for 10R principle implementation in construction industry in Sri Lanka;
- to detect CE implementation barriers in the Sri Lankan construction industry.

The study was conducted by formulating the following research questions:

1. What are the drivers of circular economy principle implementation in the construction industry of Sri Lanka?
2. What are the challenges and barriers of circular economy principle implementation in the construction industry of Sri Lanka?

1. LITERATURE REVIEW

1.1. The Concept of Circular Economy

The conventional model of linear economy "take-make-dispose" has consistently failed to meet global sustainability challenges such as ongoing economic development, environmental protection, and social well-being (Jawahir & Bradley, 2016). According to its description, the CE is a system designed to be restorative and regenerative in order to decouple economic growth from resource usage (Ghisellini et al., 2016). Moreover, MacArthur (2013) defines the phrase "circular economy" as an industrial system that is designed to be restorative, focuses on renewable energy, reduces, tracks, and totally eliminates the consumption of harmful chemicals, and effectively removes waste via smart design.

The CE focuses on waste reduction, reuse, recycling, and resource recovery. It is a cutting-edge approach for achieving long-term growth (Mele & Poli, 2015). It is a requirement for preserving the current way of life by maintaining the value of resources and keeping them in use (Kalmykova et al., 2018). CE uses the product's end-of-life as a substantial economic material resource (Allacker et al., 2014). It is exceedingly difficult to transition from a linear economy (LE) to a circular economy (CE). Yet, doing this will help achieve long-term sustainability goals (Moallemi et al., 2020). By maintaining resources in the productive cycle for as long as possible, CE guarantees that the greatest value is recovered from the available resources (Sverko Grdic et al., 2020). CE functions as a regenerative process by maximizing raw material use while lowering emissions and waste output through repair, repurposing, reuse, recycling, and refurbishing (Geissdoerfer et al., 2017).

The CE concept does not necessarily considers all aspects of sustainability. The social component of sustainability, which is a growing source of criticism in its relationship with sustainability, is deliberately excluded (Ghufran et al., 2022). Nonetheless, scholars, businesspeople, and politicians are interested in the benefits of using the CE paradigm to boost the economic system's sustainability (Guerra & Leite, 2021). As a result, this research is one of the first attempts to bridge this gap by supporting the implementation of CE principles in Sri Lankan construction projects.

1.2. Principles of Circular Economy

Using the CE concept is now a "must" rather than a choice. Some of the primary benefits of using CE in construction, according to Wanaguru et al. (2022), are reduced depletion of vital resources, reduced waste creation, reduced environmental hazards, the potential for economic growth, and so on. To gain the aforementioned important benefits, a good grasp of the ideas of the circular economy and its evolution is required.

The origin of circular economy concept can be found back in 1966, when American economist Kenneth Ewart Boulding drew an analogy regarding rather circular than linear flow of material resources (Boulding, 1966). It reflected a transformation from "cowboy economy", which characterizes with endless resources and ability to abandon problems, to a "spaceship economy", where limited resources had to be reused and recycled as precondition to sustainable life-support systems (Geipele et al., 2018). In late 20th century the concept was presented with the 3Rs of waste management: reduce, reuse, and recycle. The "reduction" principle tries to minimize the input of raw energy, natural resources, and waste by improving the efficiency of production and consumption processes. The "reuse" idea promotes the reuse of any non-waste components or goods that are utilized for the identical function for which they were initially conceived. It also implies cross-industry linkages in which byproducts and waste from one business can be used as raw materials and resources in another. "Recycle" is the 3R system's third element. Recycling serves to recover materials of useable value, reducing the quantity of trash that must be handled or disposed of. Although recycling is most closely connected with CE, it is not as sustainable as other concepts, such as reduction and reuse, when considering resource effectiveness and financial viability (Mapfre, 2022).

Srinivas (2021) questions if "reduce, reuse, and recycle" is sufficient. Is it necessary to take a broader and more in-depth look at the natural ecosystem and the influence that communities have on it? This was created as a 6R technique for items that have various life cycles. "Reduce", "remanufacture", "reuse", "recover", "recycle", and "redesign" are all part of the 6R process. The "remanufacture" idea requires the disassembly of items and the removal of various pieces that can be utilized in other new products. The term "redesign" refers to the process of revising the look, function, or content of a product or service in order to make it more environmentally sustainable and socially cohesive. The goal of implementing "recover" is to recover or recuperate a resource's usefulness or return a resource to its native or enhanced working state.

This has now evolved into a conceptual model of the circular economy comprised of ten principles (10R). Ten CE principles were identified: reduce, reuse, recycle, redesign, recover, rethink, remanufacture, repurpose, repair, and refurbish. The framework now additionally includes the concepts of rethink, reuse, repair, and refurbish. The "rethink" idea is an initiative to review or assess social, economic, and environmental strategies, particularly when changing aims. "Refurbish" is to make a structure more resistant to disaster dangers by updating, modernizing, or retrofitting it, or even to make its maintenance more ecologically friendly. "Repurposing" is the process of reworking a tool, technology, or commodity for a new use or form that may be substantially different from its original intended use. Finally, the term "repair" refers to the process of repairing machinery and technologies that are in bad condition or have degenerated in order to improve their effectiveness while minimizing their environmental implications (adapted from (Srinivas, 2021)).

Figure 1 depicts the 10R model designed and used in this research.

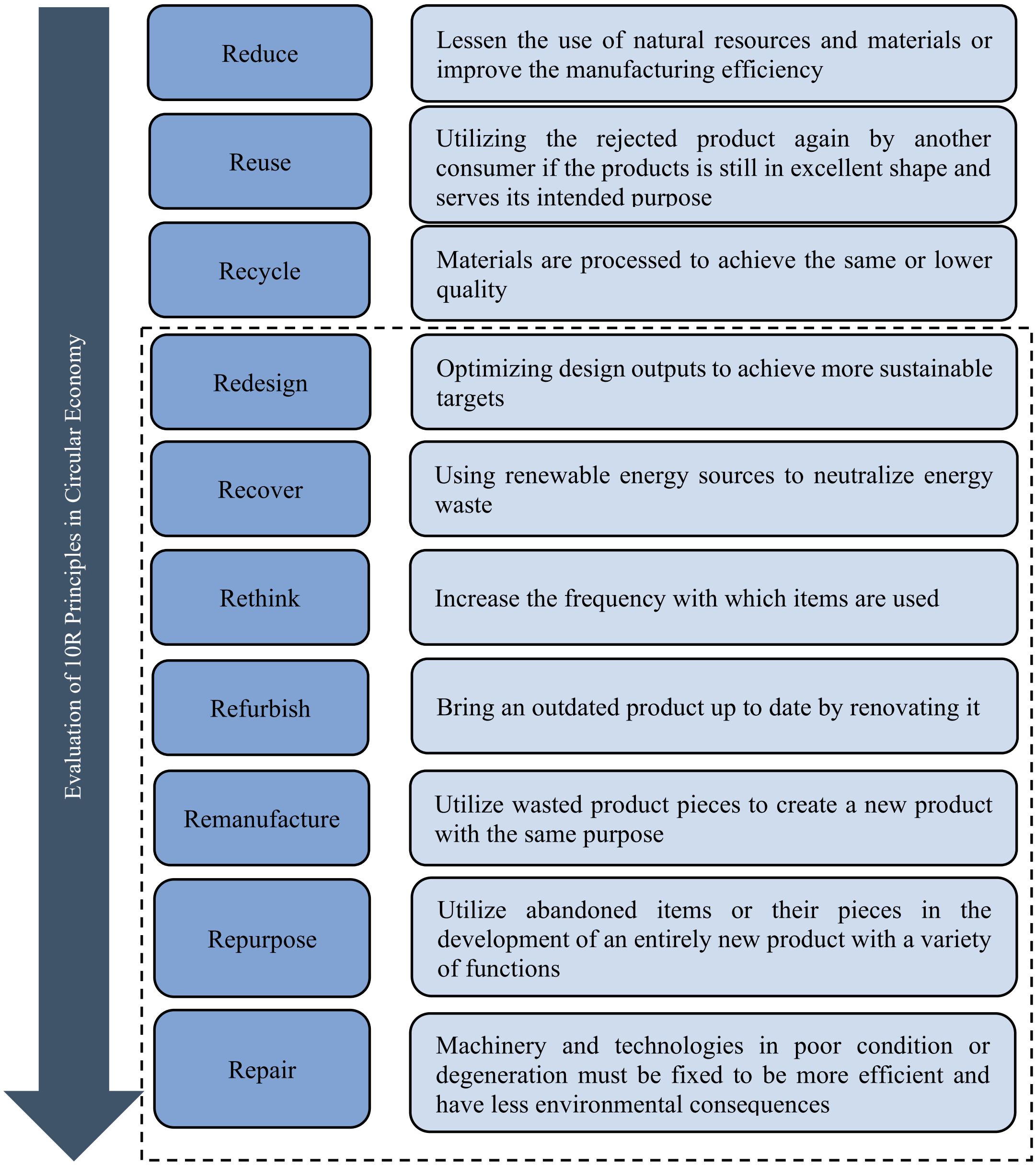

Fig. 1. Conceptual framework of 10R principles (adapted from (Srinivas, 2021)).

1.3. Circular Economy Concept in Construction Industry

The built environment and construction industry are the largest users of natural resources, accounting for more than one-third of worldwide yearly energy production, putting a substantial burden on the environment (Munaro et al., 2020). Notwithstanding its benefits to the economy, society, and environment, the construction industry generates the most waste globally (Nuñez-Cacho et al., 2018). According to Kibert (2016), end-of-life activities and operations, which mostly comprise demolition, account for more than half of all waste produced in the construction sector. Just around 30 % of these materials, however, are recycled or reused (MacArthur, 2013). As a result, there is a clear and evident need to lessen this impact by changing from linear to more circular consumption patterns, which will reduce the impact of the built environment (Arora et al., 2020).

The construction business, as a large worldwide consumer of commodities such as energy, materials, and resources, makes CE ideas particularly applicable to the construction industry (Türkeli et al., 2018). In the next few years, resource productivity will become a top issue in the construction industry. Using CE principles might boost resource productivity (Smol et al., 2015). A CE analysis in the construction industry is critical, since it is one of the top goals for national economic growth (Suárez-Eiroa et al., 2019). The lack of literature focusing on the application of CE principles in the Sri Lankan construction sector demonstrates that this is especially true for underdeveloped countries like Sri Lanka.

The CE concept is quickly gaining traction for some of the most pressing global, intersecting sustainable development challenges (Sparrevik et al., 2021). By evaluating significant literature on various CE techniques and frameworks produced by research academics, this study will offer 10 CE principles that were taken into consideration while building the CE-based 10R assessment and adaptation framework for the construction industry in Sri Lanka. This is one of the first studies to address this gap by arguing for the use of CE principles during the construction phase of Sri Lankan construction projects.

1.4. Barriers to Circular Economy in Construction Industry

CE development may be hampered by unfavorable hurdles or behavioral constraints (Urbinati et al., 2021). Due to hurdles, stakeholders are unable to adopt attitudes or practices that facilitate a shift towards CE (Bilal et al., 2020). As a result, low indicator performance ratings may suggest insufficient overall CE development (Adabre et al., 2022). Mangla et al. (2018) identified 16 barriers to circular supply chains (CSC) for poor countries based on a review of the literature, Interpretive Structural Modelling (ISM), and Multiplication cross-impact matrix applied to a ranking (MICMAC) analysis methods. The two most significant hurdles identified were a lack of environmental rules and regulations as well as a lack of favorable tax policies to encourage circular models. According to Charef et al. (2021), there are three major kinds of obstacles in the building industry: social, economic, and environmental.

The establishment of a CE system in the past few decades has resulted in a paradigm shift, since it aims to keep materials in a closed loop to retain their maximum value, reducing waste generation and resource exploitation for construction (Benachio et al., 2020). One of the construction industry's flaws is its siloed working methods in which phases and stakeholders are separated and have limited communication. It is critical to create a more complete plan within the framework of the CE, incorporating all stakeholders and, as a consequence, all asset stages as indicated by Charef et al. (2021). Xue et al. (2010) used a questionnaire-based survey to measure CE awareness in China at the national and municipal levels. Despite the fact that the CE concept is widely understood, 16 % of the authorities had never heard about it. They argued that public awareness of politicians might be improved through workshops, newsletters, and media efforts. Furthermore, they claimed that "lack of public awareness" and "lack of financial assistance" are the primary impediments to CE. Also, they emphasized that there is a mismatch between CE rules and actual circumstances in China.

2. RESEARCH METHODOLOGY

In comparison to other research methodologies, qualitative research allows scholars to gain a full grasp of unique and evolving themes (Yin, 2011). Further, quantitative analysis becomes problematic when the sample size of respondents is low. Furthermore, unlike quantitative studies in which the relevance of a piece of data is defined by its frequency of presence, qualitative studies simply require the identification of a single piece of data or code to be included in the analytic framework (Mason, 2010).

According to the background study, existing information on using CE in the Sri Lankan construction sector is at an early stage. This hampered the possibility of gathering a significant sample of respondents to conduct the collection of data. In such a scenario, where current knowledge about the study region is restricted and the capacity for collecting a large sample is limited, a qualitative research technique was chosen based on literature recommendations. According to Saunders et al. (2009), an interview is an intentional dialogue between two or more persons that allows for useful and in-depth insights into a certain field of research. Collecting the perspectives of subject matter experts allows to gain in-depth insights from their expertise and knowledge (Wijewansha et al., 2021). As a result, semi-structured questionnaire was prepared as the optimal data collecting strategy for this study based on the qualitative research method used and the nature of the research topic. Semi-structured questionnaires allowed the researcher to acquire specified information for comparisons while also gathering any additional information stated by respondents throughout the data collecting process.

Purposive sampling was used for this study, which included semi-structured questionnaires with construction experts. The survey was conducted via the internet using Google forms. The questionnaire was distributed to 71 industry experts, who submitted 53 responses. In social research surveys, a response rate of 50 % is considered satisfactory (Wanaguru et al., 2022). Accordingly, the response rate to the questionnaire survey was 74.6 %.

3. RESEARCH FINDINGS

3.1. Occupational Profile of the Respondents

A total of 53 respondents from various professional backgrounds were chosen. The vast majority of respondents (62.3 %) described themselves as engineers. This implies a high proportion of engineering experts among the respondents. 13.2 % of those respondents said they worked as consultants. This group is likely to include individuals who offer expert advice and help in a variety of sectors. According to the survey, 9.4 % of respondents described themselves as main contractors in the construction industry. Individuals or businesses in this category are in charge of supervising and managing construction projects. 7.5 % of those surveyed said they supplied materials and equipment. This category is likely to contain companies that provide materials and machinery to construction operations. A total of 3.8 % of respondents identified themselves as designers or architects. This group is most likely made up of specialists involved in project design and planning in sectors such as architecture, interior design, and urban planning. Manufacturers and subcontractors each accounted for 1.9 % of responses. Manufacturers are likely to represent individuals or businesses active in the manufacture and fabrication of items, whereas subcontractors are likely to operate under major contractors, specializing in certain activities or services. The occupational profile of the survey participants is illustrated in Fig. 2.

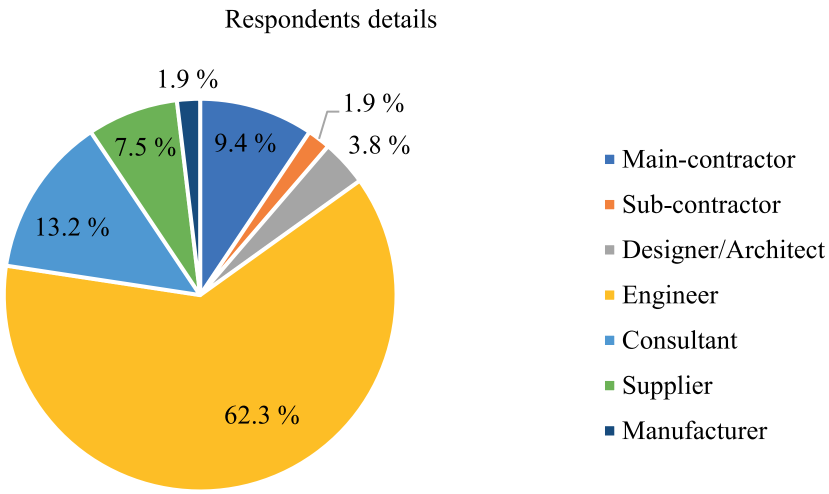

Fig. 2. Occupational profile of the respondents (developed by authors).

The majority of respondents (54.7 %) had 1 to 5 years of experience in the construction sector. This is beneficial, since responders have knowledge of the construction operations in Sri Lanka. According to the survey results, 18.9 % of respondents had less than one year of experience in construction sector. 11.3 % of respondents stated that they have worked in construction for 10 to 15 years. A similar proportion (7.5 %) of respondents had worked in construction for more than 15 years and for 5 to 10 years.

Even though the respondents have worked in the construction sector for several years, their engagement in sustainable efforts is limited. According to the survey results, 60.4 % of the 53 respondents had less than a year of experience with sustainable activities. 28.3 % of respondents stated that they had been involved in sustainable development initiatives for 1 to 5 years. 5.7 % of the respondents said they had been working on sustainable development for 5 to 10 years. 3.8 % of survey respondents said they had worked in various sustainable methods for 10 to 15 years. Only 1.9 % of those respondents said they had been engaged for sustainable development in the sector for more than 15 years. Figure 3 illustrates the experience of respondents in construction industry and sustainable initiatives.

Fig. 3. Experience of respondents in the construction industry and sustainable initiatives (developed by authors).

3.2. Awareness of Circular Economy Principles

The survey results on awareness about CE concept give intriguing insights into respondents' level of comprehension. It is noteworthy that 47.2 % of respondents, when asked about understanding of CE principles, chose the option "yes", which indicates that a significant proportion of the sample population understands the principles of CE. These people are probably familiar with the fundamental principles and practices related with this sustainable economic model, such as resource efficiency, waste minimization, and closed-loop systems. However, it is worth noting that a substantial percentage of respondents (35.8 %) expressed a partial understanding of CE principles. This implies that, although they may have a basic understanding or awareness of particular components of the concept, they may not have a thorough comprehension of the full framework. Furthermore, 17 %

of respondents claimed to have no knowledge of CE principles. This answer indicates lack of awareness and understanding among the studied population. Steps need to be taken to close this gap through focused educational programs, an unambiguous explanation of CE and related concepts, and the distribution of relevant information.

3.3. Awareness of the Sustainable Approaches to Implement 10R Framework

The suggested 10R principles are reduce, reuse, recycle, redesign, recover, rethink, refurbish, remanufacture, repurpose, and repair. Each respondent was given four choices in which they had to prioritize and select the most appropriate measures for effectively introducing each R principle in the industry. Table 1 demonstrates respondents' preferences for priority tasks for executing the first 3R principles.

Table 1. Priority Activities in Initial 3R Principles Proposed by Respondents (developed by authors)

CE Principle	*Priority Activity*	*Frequency (as %)*
Reduce	Develop a proper waste management framework	71.7 %
	Minimize use of non-renewable energy sources	71.7 %
	Quantify construction and demolition wastes and identify reusable products	50.9 %
	Minimize use of toxic &hazardous materials	32.1 %
Reuse	Wisely track material consumption activities	64.2 %
	Utilize construction & demolition waste within the industry	56.6 %
	Identify opportunities to utilize municipal solid wastes in the construction industry	39.6 %
	Engage community in the waste management practices and identify solid wastes to use in construction	37.7 %
Recycle	Recycle construction & demolition wastes	75.5 %
	Identify opportunities to utilize recycled materials in the design stage	71.7 %
	Encourage public & private sector to initiate recycling plants	66.0 %
	Implement more recycling plants	28.3 %

As mentioned earlier, the initial 3R framework was further developed into 10R framework by introducing 7 more valuable principles. Table 2 demonstrates respondents' preferences for priority tasks for executing the extended 7R principles.

Table 2. Priority Activities in Extended 7R Principles Proposed by Respondents (developed by authors)

CE Principle	*Priority Activity*	*Frequency (as %)*
Redesign	Consider using sustainable design strategies in design phase	79.2 %
	Focus on sustainable construction guidelines	75.5 %
	Engage green certified license holders in the design stage	45.3 %
	Adapt modular construction strategies	37.7 %
Recover	Encourage the use of renewable energy sources	81.1 %
	Conduct life cycle assessment to quantify the waste emissions	50.9 %
	Adapt Life Cycle Cost (LCC) saving strategies	47.2 %
	Check for opportunities to utilize discarded equipment & materials	39.6 %
Rethink	Consider design optimization techniques with modern BIM tools	77.4 %
	Review design strategies and concepts prior to implementation	66.0 %
	Ensure that circularity principles are achieved by completion of tasks	45.3 %
	Engage green certified products in construction phase	41.5 %
Refurbish	Encourage clients to use constructed temporary structures as a part of the project once it is completed	77.4 %
	Encourage designers to provide alternative designs with existing structure, if a structural part has changed, rather than demolition	73.6 %
	Focus on utilizing discarded products and bringing it up to date	37.7 %
	Use existing structures on site	24.5 %
Remanufacture	Use site waste materials as a temporary option to perform specific tasks	67.9 %
	Limit raw material extraction	60.4 %
	Advance technicality of products to increase the potential of use in other activities	58.5 %
	Create new products from construction waste to use in another task	45.3 %
Repurpose	Collect usable equipment and materials from completed projects rather than purchasing new ones	83.0 %
	Get the optimum usage of equipment on site	62.3 %
	Encourage material suppliers to upcycle their products	54.7 %
	Sell/rent machineries after usage rather than abandoning them	41.5 %
Repair	Initiate quality checks on each activity	77.4 %
	Implement strict regulations for maintenance	77.4 %
	Repair broken tools and use them without discarding	39.6 %
	Provide training for workers to repair equipment on the site	32.1 %

3.4. Barriers to Implement CE Framework

The research also focused on the barriers for implementing 10R principles in Sri Lanka's construction sector. According to the results of the survey, 81.1 % of the respondents considered lack of knowledge about CE principles as the primary barrier to Sri Lanka's transition to CE. Another significant barrier, according to respondents, was the political corruption in the country (77.4 %). An equal percentage of respondents (64.2 %) identified higher expenses for adopting CE in the industry and low industry demand for CE as barriers for transition to CE. Furthermore, an equal proportion of the sample (62.3 %) stressed that resistance to change of stakeholders and inadequate policies and regulations act as barriers for transition to CE. Another key barrier to implementing CE, according to 47.2 % of respondents, is lack of research activities in the subject area. Furthermore, respondents see that the lack of awareness of the impact on the environment and pertaining socio-economic crisis (39.6 % and 37.7 %, respectively) merely act as barriers for establishing CE model in the construction industry. It is worth noting that respondents do not feel that lack of space in site storage (9.4 %) does not have a significant influence on CE implementation, but its impact could be significant. Figure 4 depicts the barriers identified according to respondents.

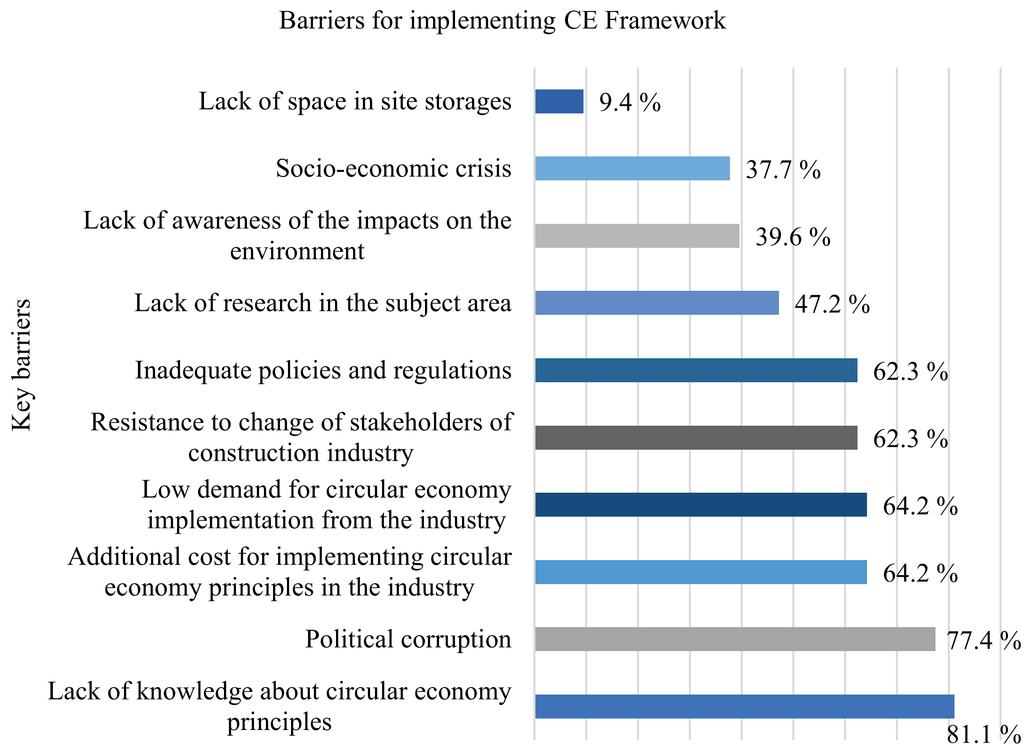

Fig. 4. Respondents' perception on barriers for implementing a CE framework (developed by authors).

3.5. Drivers for Implementing CE Framework

The large proportion of respondents (77.4 %) who emphasized the necessity of training and awareness workshops demonstrate a definite need for capacity-building activities. The substantial amount (75.5 %) of respondents stressing the need of government support demonstrate the realization that regulatory and policy structures play an important role in developing sustainable practices. Furthermore, 73.6 % of respondents believe it is critical to encourage designers to use CE principles throughout the design phase. With 62.3 % of respondents highlighting the necessity of recycling processes and the reuse of secondary raw materials, the construction sector has the potential for considerable resource savings. Furthermore, 54.7 % of respondents believe that more funding for research in the subject area is required. This underlines the significance of developing evidence-based knowledge and innovative solutions. Moreover, 43.4 % of respondents indicated waste tracking and segregation as a feasible approach to discovering possible waste for reuse. A smaller portion of respondents (37.7 % and 35.8 %, respectively) highlighted the significance of marketing tactics and cost-effective waste disposal strategies as an opportunity for proper CE transition. Figure 5 illustrates the drivers identified according to respondents' perceptions.

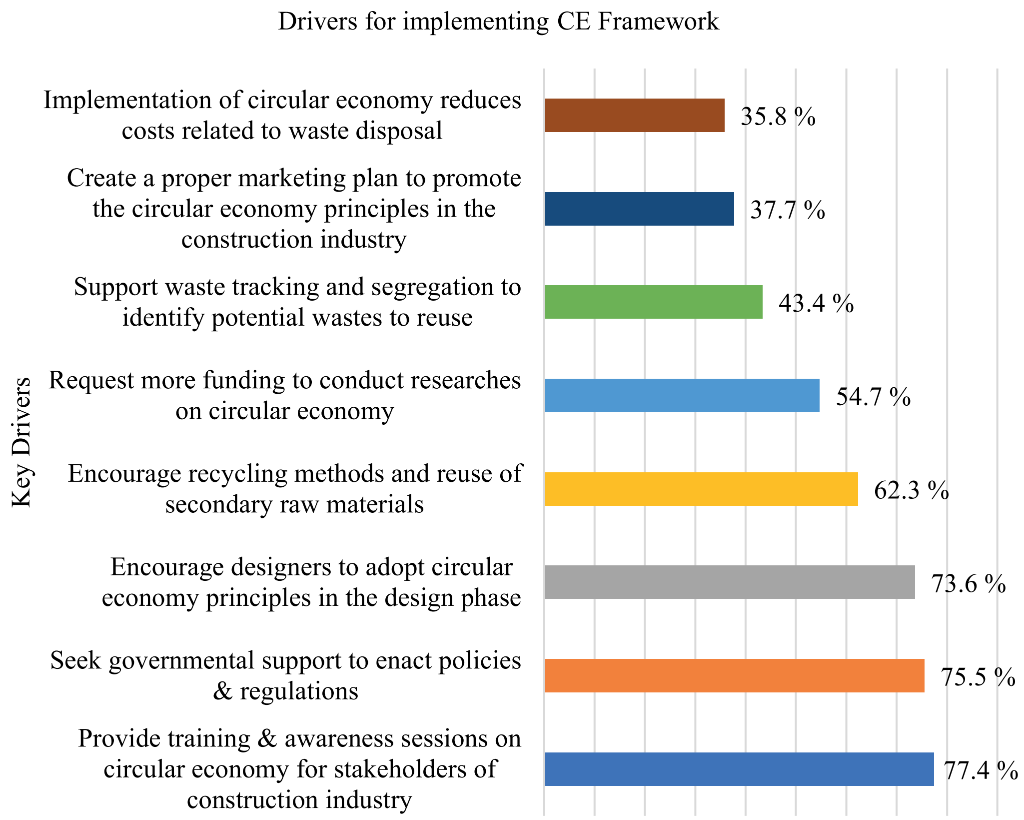

Fig. 5. Perception of respondents on drivers for implementing CE framework (developed by authors).

4. DISCUSSION

According to the survey results, a significant percentage of respondents understand the principles of the CE. This finding implies that there is a base of knowledge and awareness that might serve as an initial foundation to carry out circular practices in the Sri Lankan construction sector (Gunarathne et al., 2021). It is encouraging to see that a significant percentage of people in the business have the knowledge required to spearhead the transition to a more environmentally friendly and resource-efficient construction industry. However, the results indicate that a significant proportion of respondents have a partial awareness of CE principles. This suggests that there is an opportunity for improvement in teaching and enlightening Sri Lankan construction stakeholders about the larger scope and potential advantages of circular processes. Addressing this knowledge gap is critical for the successful deployment of circular techniques and their effective incorporation into construction procedures. According to the survey, it was found that there is some community that does not have any sort of awareness about CE principles. This emphasizes the critical need for educational activities and awareness campaigns in Sri Lanka's building sector.

According to Caiado et al. (2018), the first step to accomplish the transition is through seminars, workshops, training courses, and educational campaigns. The construction sector could accelerate the transition to more sustainable practices by empowering stakeholders with information about CE concepts, best practices, and emerging technologies (Singh et al., 2021). Training programs may be developed to inform industry professionals, including contractors, engineers, designers, material suppliers, and others who are involved in the construction industry, on the advantages and practical use of CE ideas. It is critical to collaborate with government agencies and policymakers to establish and implement supporting laws and regulations that encourage and enable the implementation of CE concept (Ghufran et al., 2022). These policies may include tax breaks, subsidies, and legal requirements for green construction. Designers have an important part in incorporating CE concepts from the start of a project. They may help reduce the generation of waste and optimize resource use by focusing on concepts like material efficiency, modularity, mobility, and deconstruction in their designs (Wanaguru et al., 2022). It is critical to encourage collaboration among engineers, architects, and other design experts in order to efficiently integrate CE principles in the construction sector. Implementing effective waste management systems, encouraging the use of recycled materials, and forming partnerships with recycling facilities may all assist to reduce dependency on virgin resources, reduce waste output, and lessen the environmental impact associated with construction operations (Gunarathne et al., 2021). A well-designed marketing strategy may build awareness, generate demand, and promote the benefits of using circular economy concepts in the construction business (Yu et al., 2022). It might include focused communication initiatives, highlighting successful case studies, and emphasizing the environmental and financial advantages of sustainable construction techniques. Waste management in the construction industry decreases material usage, lowers disposal costs, and decreases environmental effects (Wanaguru et al., 2022).

The following 10R framework, as shown in Fig. 6, which comprises CE principles, is proposed to be implemented.

R1 – Reduce	• Develop a proper waste management framework • Minimize use of non-renewable energy sources • Quantify construction and demolition wastes and identify reusable products
R2 – Reuse	• Wisely track material consumption activities • Utilize construction & demolition waste within the industry • Identify opportunities to utilize municipal solid wastes
R3 – Recycle	• Recycle construction & demolition wastes • Utilize recycled materials in the design stage • Encourage public & private sector to initiate recycling plants
R4 – Redesign	• Consider using sustainable design strategies in design phase • Focus on sustainable construction guidelines • Engage green certified license holders in the design stage
R5 – Recover	• Encourage to use renewable energy sources • Conduct life cycle assessment to quantify the waste emissions • Adapt Life Cycle Cost (LCC) saving strategies
R6 – Rethink	• Consider design optimization techniques with modern BIM tools • Review design strategies and concepts prior to implementation • Ensure that circularity principles are achieved by completion
R7 – Refurbish	• Encourage clients to use constructed temporary structures as part of the project once it is completed • Encourage designers to provide alternative designs with existing structure • Focus on utilizing discarded products and bringing it up to date
R8 – Remanufacture	• Use site waste materials option to perform specific tasks • Limit raw material extraction • Advance technicality of products to increase the potential of use in other activities
R9 – Repurpose	• Collect usable equipment and materials from completed projects rather than purchasing new ones • Get the optimum usage of equipment on site • Encourage material suppliers to upcycle their products
R10 – Repair	• Initiate quality checks on each activity • Implement strict regulations for maintenance • Repair broken tools and use them without discarding

Fig. 6. Proposed 10R framework (developed by authors).

CONCLUSIONS

In conclusion, the research findings highlight the current status and potential for implementing a CE framework in the Sri Lankan construction sector. The study reveals a mixed level of awareness and understanding of CE principles among construction stakeholders. While a significant proportion of respondents demonstrated a good understanding of CE, there is also a substantial percentage with only partial awareness or no knowledge at all. This underscores the importance of targeted educational initiatives and awareness campaigns to bridge the knowledge gap and foster a comprehensive understanding of CE concepts.

The research also identifies various barriers and drivers for implementing CE in the construction sector. Lack of knowledge about CE principles, political corruption, higher expenses for implementing CE principles, low industry demand, resistance to change, and inadequate policies and regulations emerge as significant barriers (Charef et al., 2021). On the other hand, training and awareness workshops, government support, encouragement for designers, recycling and reuse, financial support for research, waste tracking and segregation, marketing tactics, and cost-effective waste disposal strategies are identified as drivers for CE implementation (Atapattu et al., 2022).

To effectively implement a CE framework, the study recommends involving multiple stakeholders, including legislators, educators, industry experts, and public collaboration and training programs, as well as capacity-building activities to be utilized to empower stakeholders with knowledge and capable of sharing good practices. Additionally, supportive policies and regulations need to be established to incentivize and facilitate sustainable practices in the construction sector. Designers should be encouraged to integrate CE principles from the early stages of projects, and waste management systems and recycling partnerships should be developed to reduce dependence on virgin resources and minimize waste generation.

Overall, the findings underline the need for a focused effort to enhance awareness, foster collaboration, and address barriers in order to promote the transition of the Sri Lankan construction sector towards a more sustainable and resource-efficient future. By implementing the recommended strategies and leveraging the identified drivers, the industry can embrace the principles of CE, reduce environmental impact, and contribute to long-term sustainable development.

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