

ADAPTABILITY OF CIRCULAR ECONOMY PRINCIPLES IN CONSTRUCTION: A CASE OF HIGH-RISE RESIDENTIAL BUILDINGS IN SRI LANKA

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Abstract. The construction industry significantly contributes to environmental degradation through resource and energy consumption and waste generation. The concept of circular economy (CE) enables addressing the above concerns via its principles. This study assesses the adaptability of CE principles at the construction stage of high-rise residential buildings in Sri Lanka. A qualitative approach was adopted, employing a multiple case study strategy. Data were collected through semi-structured interviews with subject matter experts from the three selected buildings, with two experts per case due to a lack of professionals with CE expertise in the local context. Content analysis and cross-case comparisons were conducted. Findings showed CE awareness is emerging in Sri Lanka, but implementation is limited. Amongst the R concepts, 'Reduce' is moderately applied through material management and prefabrication. 'Reuse' practices are minimal, while 'recycling' is constrained by knowledge gaps, energy requirements, and infrastructure limitations. 'Redesign' was at a nascent stage, with partial adoption of modular designs, while 'Reclassification' was rarely practised due to a focus on short-term material use. 'Renewability' demonstrated potential by incorporating design features that facilitate future renewable energy installations. The study highlights the necessity for enhanced awareness, supportive procurement mechanisms, and targeted capacity building to encourage CE integration in Sri Lanka.

Keywords. 6R Principles; Circular Economy; Construction; Sri Lanka; Strategies.

1. Introduction

The construction industry is a multifaceted and dynamic sector that consists of the design and construction of new structures as well as the refurbishment and renovation of existing structures (Celik et al., 2017). It is identified as a powerful source of business and employment opportunities and a major contributor to the gross domestic product (GDP) of an economy (Sapuyay, 2016). Although construction is an essential component of the growth and development of the socio-economic system, the industry's negative environmental effects often outweigh its benefits (Yusof et al., 2017; Hussin et al., 2013). Construction uses more than 30% of natural resources and recovers just a small portion at end-of-life stages (Guerra and Leite, 2021; Anastasiades et al., 2020; Eberhardt et al., 2019). Earlier estimates suggest that only 20–30% of construction materials are reused or recycled when a building reaches the end of its useful life (Ellen MacArthur Foundation [EMF], 2014). More recent studies indicate that recovery rates remain low and vary significantly across regions, with a substantial proportion of materials still being downcycled into low-value applications or disposed of in landfills, reflecting persistent inefficiencies in current waste management practices (Bayram & Greiff, 2023).

Construction and demolition waste (CDW) amounts to billions of metric tonnes annually and is estimated to account for approximately 25-35% of the world's solid waste (Yeheyis

et al., 2012), with some estimates indicating shares as high as 40% depending on regional definitions and measurement approaches (Sirimewan et al., 2025). This waste is predominantly disposed of in landfills all over the world, resulting in environmental, economic, and social impacts, including water pollution, greenhouse gas emissions, and land degradation (Jin et al., 2019; Akanbi et al., 2018; Ding et al., 2016). These issues are mostly the consequence of the construction industry's adoption of the linear economic model (take-make-dispose) (EMF, 2015). Accordingly, the construction industry urgently needs to implement creative eco-efficiency measures to reduce its impact on the environment while maintaining or expanding its economic growth (Zuo & Zhao, 2021; Braungart et al., 2007).

The circular economy (CE) is a promising approach to promote environmental sustainability while balancing the industry's contribution to socioeconomic development (Wijewansa et al., 2021). According to Grdic et al. (2020), the CE focuses on retaining the value of materials, products, and components for a maximum duration within an economic system. CE principles promote the efficient use of materials through recycling, reusing, and utilising sustainable materials while avoiding waste generation and disposal in landfills (Hossain et al., 2020). Beyond its environmental benefits, CE supports economic benefits such as growth in GDP, reduced unemployment, the saving of materials, and enhanced supply chain stability and price volatility (Morgan & Mitchell, 2015). For instance, the integration of CE principles in the European Union is expected to increase the GDP of a region by approximately 4% by 2030 (Benachio et al., 2020).

Sri Lanka is experiencing ecological challenges because of unsustainable construction practices in the sector, including excessive resource and energy consumption and rising levels of waste generation (Athapaththu et al., 2016). This intensified the national focus on enhancing the sustainability of the Sri Lankan construction industry (Liyanage et al., 2019). However, the country still needs significant progress to fulfil the global standards for sustainable construction (Fernando et al., 2022). Furthermore, adoption of the CE concept in the construction sector of Sri Lanka is still in its primitive stages due to a lack of awareness and familiarity with the concept and is only partially applied within the industry (Wijewansa et al., 2021; Liyanage et al., 2019).

Previous research on the implementation of CE in the construction industry has primarily focused on the construction stage, instead of breaking down the potential of CE principles into specific construction activities (Adams et al., 2017; Ghisellini et al., 2018). This represents a significant gap, since construction projects are inherently multi-activity processes where CE interventions may have differentiated carbon reduction potentials and operational implications (Pomponi & Moncaster, 2017). Moreover, numerous studies investigated the application of CE principles in the Sri Lankan construction industry. For example, Wanaguru et al. (2022) developed a 10R-based evaluation framework for material selection to reduce the wastage of materials in building construction projects in Sri Lanka. Similarly, Wijewansa et al. (2021) identified a set of 6R-aligned activities applicable during the pre-construction stage. Gowsiga and Thayaparan (2023) noted the prominence of 3Rs (reduce, reuse, and recycle) within sustainable urban development projects, while recommending CE strategies for CDW minimisation based on a desk study. Furthermore, Fernando et al. (2022) observed that CE implementation remains in its

infancy, hindered by various barriers. Notably, the practical adaptability of CE principles during the construction stage of buildings is limitedly assessed by these studies. Moreover, limited studies have focused exclusively on high-rise residential buildings, a sector that has expanded rapidly in post-conflict Sri Lanka due to urbanisation trends (Ranagalage et al., 2020; Karunasena et al., 2016).

To address this research gap, this study aims to assess the adaptability of CE principles in the construction of high-rise residential buildings in Sri Lanka. The research methodology is presented in the next section, followed by the research findings and discussion. Finally, the conclusions are provided.

2. Circular Economy Concept and R-Principles

CE represents a systemic shift from the traditional linear “take-make-disposal” economic model towards a regenerative system that minimises resource input and waste output by narrowing, slowing, and closing material and energy flows (Geissdoerfer et al., 2017; Antunes et al., 2022). Rather than focusing solely on waste management, CE emphasises narrowing, slowing, and closing material and energy loops, thereby improving resource efficiency and reducing environmental impacts (Luttenberger, 2020). Its relevance has been increasingly recognised in policy frameworks, with the construction sector identified as a priority area due to its high resource consumption and waste generation (Leising et al., 2017). However, despite this recognition, the application of CE in the construction industry, especially in high-rise residential buildings remains limited, primarily due to materials intensity, lifecycle stages, and fragmented stakeholder structure (Pomponi & Moncaster, 2017).

The CE concept has evolved from multiple theoretical foundations, including industrial ecology, industrial symbiosis, and cradle-to-cradle, all of which share a closed-loop resource perspective (Lieder & Rashid, 2016). Among these, the R-framework, also referred to as R-imperatives, has emerged as a central principle of CE, offering a systematic approach to resource efficiency and value retention (Kirchherr et al., 2017). The framework has evolved progressively from the basic 3R framework (reduce, reuse, and recycle) to more expanded versions such as 4R, 9R, 10R, and 11R frameworks, which introduce increasingly detailed recovery and regeneration strategies (Cimen, 2021; Reike et al., 2018; van Buren et al., 2016). While these extended frameworks provide conceptual richness, they often become less practical for industry application due to increased complexity and limited clarity in implementation pathways.

However, this study adopts the 6R framework, which includes Reduce, Reuse, Recycle, Redesign, Reclassification, and Renewability, as it provides a balanced structure that integrates both operational and design-oriented circular strategies relevant to construction activities. Unlike broader multi-layered frameworks, the 6R framework is more suitable for construction contexts where decision-making is distributed across design, procurement, and site execution phases (Ghisellini et al., 2016). According to Charef et al. (2021), the 6R framework offers a useful and flexible lens through which to evaluate CE practices, including material reuse, modular design, and the use of renewable

materials. Furthermore, prior studies also suggest that simplified and context-specific R-frameworks enhance practical adoption by aligning better with industry workflows and technical constraints (Kirchherr et al., 2017). Therefore, the selection of the 6R framework in this study is justified based on its contextual relevance to high-rise residential construction and its ability to bridge theoretical CE concepts with practical implementation realities. Table 1 presents the description of the selected 6R principles of the circular economy.

Table 1: Description of 6R principles of Circular Economy

| 6R Principles | Code | Description | Source |
|------------------|------|---|---------------------------|
| Reduce | R1 | Lessen the consumption of resources and the production of waste. | (Reike et al., 2018) |
| Reuse | R2 | Continue to use any resource in its current state after another user no longer finds it useful. | (Sarfraz et al., 2021) |
| Recycle | R3 | Material is processed to obtain a new product. | (Cimen, 2021) |
| Redesign | R4 | Design of products that can be dismantled and reused at the end of their useful lives | (Ghisellini et al., 2016) |
| Reclassification | R5 | Classification of materials into the two components, such as technical and nutrients/biological | (Wijewansa et al., 2021) |
| Renewability | R6 | Use renewable materials and energy. | (Geng et al., 2013) |

3. Research Methodology

The aim of this study is to assess the adaptability of CE principles in the construction stage of high-rise residential buildings. A qualitative approach was adopted to collect in-depth information since CE is a new concept in the Sri Lankan construction industry. According to Yin (2018), the case study research strategy is more applicable when extensive and “in-depth” descriptions are required for some social phenomena. Accordingly, a case study was selected as the most suitable strategy for this research. As per Yin (2011), multiple cases are employed for repeating the same process with the intention of deriving a better result. Moreover, in the Sri Lankan context, any building that is equal to or above four stories is considered a high-rise (Athapaththu et al., 2016). Colombo city has been experiencing rapid urbanisation, with high-rise residential buildings being constructed at an unprecedented pace. Therefore, six ongoing high-rise residential building projects located in the Colombo district were identified through the internet survey. A preliminary study was conducted among those six to identify the level of exposure and the application of CE principles. It was observed that only three projects among them had a greater level of exposure to and adaptability to CE principles during the construction stage. Therefore, those three ongoing high-rise residential building construction projects were selected as cases for the empirical investigation. These cases were selected using purposive sampling as information-rich contexts with observable engagement in CE practices. The selection followed a logic to enable comparison of CE implementation across comparable high-rise residential projects rather than statistical generalisation. The selected cases were named Case A, Case B, and Case C.

A semi-structured interview is a qualitative data collection method that gives the opportunity to explore responses in more detail with flexibility (Kansters, 2020). Thus, semi-structured interviews were conducted with two (2) respondents from each case with a high degree of familiarity with CE practices to examine the application of CE principles and to identify suitable strategies for adopting CE principles in the construction stage of high-rise residential buildings. Purposive sampling was used to choose the respondents by focusing on professionals who were knowledgeable about CE-related activities and heavily involved in building decision-making. Active involvement in the present project's construction phase and a minimum of five years of industry experience were the requirements for selection. Two respondents per case were deemed sufficient to provide in-depth, role-specific insights, consistent with qualitative case study research where emphasis is placed on data depth rather than sample size. The limited number of cases and respondents restricts the generalisability of the findings, even though the multiple case study approach deepens knowledge. Furthermore, the emerging nature of CE in Sri Lanka may have influenced the depth of responses, as practitioner knowledge is still developing. Table 2 provides an overview of those cases and the profiles of the interview participants in the selected cases.

Table 2, Details of cases and profiles of interview participants

| Details of Building | Case A | | Case B | | Case C | |
|------------------------------|-----------------------|-------------------|-----------------------|-----------|-----------------------|-------------------|
| Building type | Dual tower | | Single tower | | Single tower | |
| Gross Floor Area | 44,100 m ² | | 15,280 m ² | | 13,200 m ² | |
| Estimated contract sum | 12.25 Bn LKR | | 4.41 Bn LKR | | 3.15 Bn LKR | |
| Date of commencement | November 2019 | | July 2021 | | June 2022 | |
| Duration of project | 48 months | | 18 months | | 36 months | |
| Profile of Respondent | | | | | | |
| Respondents Code | I-A1 | I-A2 | I-B1 | I-B2 | I-C1 | I-C2 |
| Designation | Project manager | Quantity Surveyor | Site Engineer | Architect | Site Engineer | Quantity Surveyor |
| Years of Experience | 25 | 06 | 05 | 08 | 16 | 10 |

Note: Interviewees were selected based on their direct involvement in each case study, and professional categories vary according to project organisation and role relevance.

To identify recurrent themes, patterns, and differences among the three cases, the interview data were transcribed and analysed using content analysis. A cross-case comparative approach was then employed to enhance analytical generalisation by examining similarities and differences in circular economy practices across the selected projects.

4. Research Analysis and Findings

This section presents the results on the applications of CE principles in typical construction activities of high-rise residential buildings in Sri Lanka and the strategies to integrate CE principles in the construction of high-rise residential buildings in Sri Lanka. The findings also highlight several constraints and opportunities that are specific to high-rise residential construction. As indicated in Section 2, the study uses 6R principles, including reduce, reuse, recycle, redesign, reclassification, and renewability, in examining the potential of those CE principles in physical building construction activities.

The adoption of CE principles in the construction stage of high-rise residential buildings was identified in terms of seven major typical construction activities in the selected cases. Table 3 shows typical construction activities and the respective CE principles applied in those activities in the selected cases.

Table 3: Use of CE principles in construction activities of high-rise residential buildings

| Typical construction activities | CE principles | | | | | | | | | | | | | | | | | |
|---------------------------------|---------------|---|---|----|---|---|----|---|---|----|---|---|----|---|---|----|---|---|
| | R1 | | | R2 | | | R3 | | | R4 | | | R5 | | | R6 | | |
| Cases | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| Excavation | ✓ | ✓ | | | | | | | | | | | | | | | | |
| Backfilling | | | ✓ | | ✓ | ✓ | | | | | | | | | | | | |
| Foundation work | | | | | | | | | | | | | | | | | | |
| Concrete works | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | | | |
| Masonry works | ✓ | ✓ | ✓ | | | | | ✓ | | ✓ | | ✓ | ✓ | | | | | |
| Finishes | | | | | | | ✓ | | | | | | ✓ | ✓ | | | | |
| Services installation | | | | | | | | | | | | | | | | ✓ | ✓ | ✓ |

In addition, several strategies were identified to integrate the 6R principles of CE in the construction of high-rise residential buildings in Sri Lanka. Table 4 summarises the results of the analysis with respect to each selected case.

Table 4: Strategies to integrate 6R principles of circular economy

| CE principles | Strategies | Case | | |
|--------------------|---|------|---|---|
| | | A | B | C |
| Reduce (R1) | Accurate calculation and ordering of materials | ✓ | ✓ | |
| | Adopt prefabricated module | ✓ | ✓ | ✓ |
| | Design freezing | ✓ | | |
| | Implement material management | ✓ | ✓ | ✓ |
| | Proper on-site sorting and storing of materials | ✓ | ✓ | ✓ |
| Reuse (R2) | Choose reusable and durable materials. | ✓ | ✓ | ✓ |

| | | | | |
|--------------------------|--|---|---|---|
| | Consider reusable steel/Aluminium shuttering materials | ✓ | ✓ | ✓ |
| | Develop a material bank. | ✓ | ✓ | ✓ |
| | Reuse of conservative waste materials | ✓ | | |
| Recycle (R3) | Choose materials with high recyclable content | ✓ | ✓ | ✓ |
| | Reprocess of waste materials | ✓ | ✓ | ✓ |
| Redesign (R4) | Adopt modular/standardised designs | ✓ | ✓ | |
| | Design for disassembly | ✓ | | ✓ |
| Renewability (R6) | Design for easy installation of renewable energy sources | ✓ | ✓ | ✓ |

4.1. REDUCE (R1) PRINCIPLE

As per the view of the respondents, the Reduce principle is largely used in concrete work, masonry work, and excavation, compared to other activities. Case A applied the principle extensively for both the concrete work and the excavation process, whereas the other two cases applied it sparingly. The reduce principle was applied in all three cases in the concrete works and masonry works to minimise material waste and cost. Respondent I-A1 emphasised that Case A used reusable formwork techniques, optimised concrete member sizes, and applied efficient concrete mix designs to minimise the amount of concrete needed for a given load during construction. On the other hand, Case C employed precast concrete structures (made off-site and erected on-site) for beams and slabs to reduce construction time and use less concrete, according to I-C2. Case A utilised a thin-joint masonry technique to reduce the thickness of mortar joints, whereas Case B made the partitions based on modular designs that can be readily added and removed. Moreover, Case C used masonry structures with removable connections, including mortarless connections. Further, Case A and Case B applied this principle at a considerable level during the excavation activity of high-rise buildings to minimise the excavation volume and reduce the amount of earth and rock that needs to be removed. Case B used techniques such as soil mixing, soil nailing, and underpinning to stabilise the soil and reduce the excavation volume. Furthermore, Case C has rarely used the reduce principle in the excavation, although they have used the reduce principle for backfilling activities using excavated earth materials to fill the land areas to reduce the cost of the backfilling.

In the case of reduction strategies, there are five strategies used in Sri Lankan high-rise residential building construction, as shown in Table 4. Strategies, including adopting prefabricated modules, implementing material management, and proper on-site sorting and storing of materials, are incorporated in all three cases, while other strategies are less focused due to a lack of awareness and possibilities related to those strategies. The majority (5 of 6) of respondents emphasised that the extent of application of the above-mentioned strategies of the Reduce principle depends on the procurement type of the construction projects. Participant IA-1 highlighted that "if there is a design-build or partnership-type procurement, design should be done by the contractor. Then contractors

can easily incorporate these strategies, and in traditional procurement types, it may be difficult to incorporate because the design part is done by another party." Further, design freezing is only used prominently in case A because it allows for fewer revisions and reworks after detailed drawings are completed and construction commences.

4.2. REUSE (R2) PRINCIPLE

According to Table 3, the reuse principle is considerably more prevalent in concrete works and backfilling compared to other activities, and this highlights that the reuse principle is applied in the Sri Lankan construction industry at the primary stage. In addition, Case A extensively implemented this principle for the concrete task, whereas the other two cases seldom applied it. Case A and Case B reuse the concrete waste produced during the construction process as aggregate in new concrete to eliminate the demand for virgin materials and save money on disposal costs. Further, all three cases employed reusable steel shuttering systems, and aluminium formwork systems are highly used in their cases instead of traditional wood formwork systems to reduce the need for new formwork and construction waste. In the case of backfilling, both Case B and Case C reused the soil excavated during the foundation excavation as backfill material for the site levelling and backfilling.

According to Table 4, choosing reusable and durable materials, considering reusable steel and aluminium shuttering materials, and developing material banks are the three strategies of the reuse principle that are utilised in all three cases. Interviewer I-B1 stated that they procure certified green materials, as those materials are high-grade and last longer than materials of ordinary quality. Case A and Case B employed reusable steel shuttering systems and aluminium formwork systems in their cases instead of traditional wood formwork systems to reduce construction waste. Although the reuse of structural components is not utilised in any of the cases due to the mismatch of specifications, as each building is unique, conservative waste materials produced in the construction process are rarely reused in Case A. Further, respondent I-A1 stated that they are concentrating on reusing traditional door, window, and furniture materials since sometimes they are stronger and more durable than materials found in the present market. Material banks have started to be incorporated into Sri Lankan high-rise residential building construction. Case A and Case C have storage places (e.g., land and warehouses) to store used materials for future reuse.

4.3. RECYCLE (R3) PRINCIPLE

Research findings revealed that the degree of exposure to the recycling principle is extremely uncommon in the Sri Lankan construction industry, but all three cases are taking several actions to incorporate the recycling principle into several construction activities. Furthermore, the recycling principle was applied to concrete works in contrast to other activities. For instance, Case A is considerably used to recycle the concrete wastes as aggregates for fresh concrete to gain both advantages, including minimising disposal waste and the materials required to make new concrete. In another instance, Case B utilised recycled materials as aggregates to prepare mortar or grout, and they are focusing on incorporating recycling systems for masonry waste management, such as sorting and separating materials for recycling and repurposing, which will reduce the

consumption of materials. In the activity of finishing, the recycling principle is practised by using reclaimed bricks in the facade and reclaimed wood in the interior finishes of Case A.

As per Table 4, strategies including the reprocessing of waste materials and choosing materials with high recyclable content were adopted in all three cases. Case A strictly considers the recyclable content when procuring materials for the construction, and Case B also procures the materials from green-certified suppliers as a more suitable way to improve recyclability. Further, I-B1 specified that they are focusing on selling or giving waste materials to third parties for recycling. In addition, other well-known recycling strategies, such as fly ash cement, using recycled concrete, aggregate, and wood shavings, and developing actions to recycle on-site, are very low in the Sri Lankan construction industry.

4.2. REDESIGN (R4) PRINCIPLE

According to the respondents, the redesign principle is quite novel to the Sri Lankan construction industry and is applied to a certain extent in concrete works and masonry works compared to other typical construction activities. In Case A, some of the concrete structures of the building were redesigned as precast elements that can be easily removed, transported, and assembled, whereas in Case B, precast beams and precast slabs were installed to some extent during its construction. However, Case C is being redesigned in the construction stage to incorporate modular elements that allow the easy replacement of individual components and systems.

Along with respondents' views, adopting modular or standardised designs and designing for disassembly are the strategies of the redesign principle. Respondents I-A2 and I-B2 suggested that the adoption of modular designs would be a good strategy for large-scale housing developments where identical units are built again in large numbers. Modular construction would be very suitable. Further, I-A1 stated that the concrete structures, such as columns, beams, and slabs in case A, were designed as precast elements that have removable connections, such as bolted connections, and can be easily disassembled and reused. In addition, I-B1 stated that they designed the partitions based on modular designs that can be easily installed and removed and designed some of the masonry structures with removable connections, such as mortarless connections, which are also practiced to some extent.

4.5. RECLASSIFICATION (R5) PRINCIPLE

The reclassification principle has limited applicability in the Sri Lankan construction industry, as most of the respondents were unfamiliar with it. Case A rarely implements this principle by developing specifications based on green building materials such as brick and timber, which are considerably used in masonry works and finishes. Similarly, Case B also developed the specification based on green materials like bricks, which were used for some parts of facades as finishes. With respect to the findings, the lack of knowledge of the basics of the reclassification principle is regarded as a barrier towards its

implementation, and Sri Lankan authorities must consider revising the existing specifications and introducing this reclassification principle.

4.6. RENEW (R6) PRINCIPLE

Table 3 shows that the renewability principle is gradually applied in the Sri Lankan context and needs to be improved. In all three cases, this principle is only used in the service installation activity of high-rise buildings. All the respondents agreed that the use of renewable energy during construction is limited to the Sri Lankan construction industry. I-A2 highlighted that clients have a prominent role in implementing the Renewability Principle due to the high initial cost of renewable energy and decreased client attractiveness.

5. Discussion

According to the literature, the level of CE awareness within the construction industry appears positive, and CE principles are being gradually implemented in the built environment, although practical application remains limited due to a lack of stakeholders' understanding (Akanbi et al., 2018; Eberhardt et al., 2019). In line with this, participants indicated that the construction industry in Sri Lanka is still at an early stage of adopting CE principles. While CE concepts are not explicitly promoted, they are applied to a certain extent through conventional practices. This suggests that CE implementation is incremental rather than strategically driven.

Opportunities for implementing CE principles in high-rise residential construction were identified. However, their extent is strongly influenced by the procurement pathway. This aligns with previous studies highlighting the role of procurement systems in shaping CE implementation (Akanbi et al., 2018; Eberhardt et al., 2019). The findings indicate that CE adoption is strongly shaped by procurement structure and contractual responsibilities, with integrated models such as design-build offering greater potential than traditional procurement arrangements. Furthermore, the need for value engineering proposals and cost negotiations suggests that economic considerations and client acceptance play a significant role in influencing CE adoption.

Although a wide range of CE strategies is proposed in the literature, their application in high-rise construction remains selective. Strategies such as prefabrication, material management, and on-site sorting are more commonly adopted due to their compatibility with existing practices and immediate operational benefits (Wahyu Adi & Wibowo, 2020). In contrast, more advanced strategies such as lightweight design and resource optimisation remain limited due to technical complexity and low industry readiness, indicating a gap between theoretical potential and practical implementation.

In terms of reuse strategies, the widespread adoption of reusable shuttering systems reflects a preference for economically viable and easily implementable solutions. However, the lack of structural component reuse highlights challenges related to standardisation and design compatibility (Jayasinghe & Waldmann, 2020). Similarly, despite policy encouragement for recycling (Stahel, 2013), implementation remains

limited due to infrastructure constraints, higher energy requirements, and limited technical capacity, reflecting a disconnect between policy and practice.

The Redesign Principle remains at an early stage of development in Sri Lanka, with limited integration of modularity and design-for-disassembly approaches (Ghisellini et al., 2016). This suggests that CE considerations are still not fully embedded in the design phase, reinforcing the dominance of reactive rather than proactive implementation. Likewise, the reclassification principle is rarely applied due to the absence of updated specifications and limited awareness of lifecycle-oriented material management (Wijewansa et al., 2021).

In contrast, the renewability principle is gradually emerging, particularly through design provisions that facilitate the future integration of renewable energy systems. This aligns with prior research highlighting the role of renewable energy in supporting circular transitions (Geng et al., 2013). However, its application during the construction phase remains highly constrained due to cost implications and technological limitations, indicating that its adoption is still largely design-oriented rather than operational.

The findings further reveal high-rise-specific constraints that influence CE implementation. The use of reinforced concrete limits opportunities for high-value reuse and encourages downcycling. In addition, vertical logistics and limited site space constrain material handling, storage, and reuse, making CE implementation more challenging than in low-rise projects. While prefabrication and modular construction offer strong potential in high-rise developments, their adoption is constrained by procurement structures and limited integration between design and construction phases.

A cross-case comparison shows clear variation in CE implementation. Case A demonstrates higher adoption due to stronger integration between project phases and more collaborative procurement arrangements. In contrast, Cases B and C show selective implementation focused mainly on operational strategies. Across all cases, reduction-oriented practices are most consistently applied, while redesign and reclassification remain limited due to structural and capability constraints rather than a lack of awareness. These variations highlight the importance of organisational structure, procurement pathways, and project complexity in shaping CE adoption.

Overall, the findings indicate that CE implementation in high-rise construction is shaped more by systemic and institutional factors—such as procurement structure, project delivery systems, and technical capability—than by awareness alone.

6. Conclusions

Findings showed that the application of CE principles during the construction phase is a complex process and is particularly under traditional procurement approaches. In addition, contractors play a major role in the adaptability of CE principles. The reduce principles shows the highest level of applicability, supported by strategies such as prefabricated and material management, while reuse and recycle principles are

moderately incorporated due to limited awareness and regulations support. Redesign remains at an early stage, with limited adoption of modular and disassembly-based approaches. Renewability is mainly reflected in provisions for future integration of renewable energy systems. The reclassification principle remains rarely applied due to limited expertise and technological capability.

This research was limited to only three ongoing high-rise residential buildings within the Colombo district due to the limited availability of comprehensive data on CE practices in the Sri Lankan construction industry. Future studies should expand the number of case studies and include different building types to improve the generalisability of findings. Quantitative assessments of the cost implications of CE adoption and lifecycle performance analysis would provide further insights into the practical feasibility of CE strategies in the construction industry.

This study contributes to the literature by identifying high-rise-specific constraints and opportunities in implementing CE principles. Vertical logistics, space limitations, and reliance on concrete-based construction significantly influence the adaptability of CE practices in high-rise residential projects. The findings highlight the need for stronger regulatory frameworks and incentives to promote CE adoption in the construction sector. Policymakers should consider developing guidelines for material reuse, mandating waste management practices, and encouraging the use of recycled materials through certification systems. In addition, capacity-building initiatives are required to improve industry awareness and technical knowledge of CE principles. For practitioners, the study emphasises the importance of integrating CE principles early in the project lifecycle, particularly through procurement strategies such as design-build approaches. Contractors and developers should prioritise prefabrication, material management systems, and reusable formwork to enhance resource efficiency in high-rise construction projects.

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