Adoption Of A Circular Economy Framework In The Design Phase Of The Refurbishment Project

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ABSTRACT

Sustainable development in the built environment depends on minimizing environmental impact and conserving resources. In refurbishment projects, integrating circular economy (CE) principles during the design stage can significantly reduce waste and enhance resource efficiency. This study presents a tailored CE framework based on the 2D3R model, which emphasizes Design for Disassembly, Design for Adaptability, and the strategies of Reduce, Reuse, and Recycle. The framework was developed through a combination of literature review, expert interviews, and survey analysis to identify drivers and barriers to CE adoption in refurbishment. Key findings highlight the role of digital technologies particularly Building Information Modeling (BIM) in improving material traceability and facilitating lifecycle assessments. These tools support the implementation of circular strategies by enabling better planning and design decisions early in the project. The study concludes that applying the 2D3R approach in initial design phases enhances sustainability, reduces costs, and improves the adaptability and longevity of refurbished buildings.

KEYWORDS: *Circular Economy, 2D3R method, Sustainable construction, Building Information Modeling, Resource efficiency*

INTRODUCTION

The circular economy (CE) is an evolving model of sustainable development that aims to decouple economic growth from resource consumption and environmental degradation. Unlike the traditional linear model of "take, make, use, dispose," CE emphasizes restorative and regenerative design by prioritizing resource efficiency, renewable energy use, and minimization of hazardous substances (Ekins et al., 2019). The phrase "circular economy" originated in 1990 while creating a new economic model based on the law of thermodynamics by Mr. Pears and Mr. Turner (Ghisellini et al., 2016). The foundation of the contemporary CE evolved through interconnected models such as environmental economy, the green economy, and industrial ecology (Tambovceva & Titko, 2022). Earlier concepts, including Boulding's "Spaceship Earth" model and Stahel's "cradle-to-cradle" principle, further established CE's theoretical foundations (Milovic et al., 2024).

As the construction sector remains one of the largest contributors to global environmental degradation, the application of CE in this domain has garnered increasing attention. The industry is responsible for the consumption of approximately 40% of global raw materials and generates nearly 30% to 40% of all solid waste (Wijesinghe et al., 2024). Construction processes also account for 39% of carbon dioxide emissions, with 11% attributed to embodied carbon in materials and products (Dsilva et al., 2023). Moreover, construction-related activities consume significant quantities of energy, fresh water, and other natural resources, exacerbating ecological pressures (Osobajo et al., 2022). These statistics underscore the urgent need for systemic change, prompting the integration of CE principles into the construction and refurbishment sectors.

Refurbishment, defined as the process of modifying, upgrading, or extending existing structures, has emerged as a sustainable alternative to demolition and new construction. Given the escalating costs of

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infrastructure and environmental concerns in developing nations such as Sri Lanka, refurbishment offers a cost-effective and environmentally viable solution (De Silva et al., 2023a). It enables the preservation of building assets while addressing issues of deterioration, obsolescence, and changing functional requirements (Ekanayake et al., 2018). When aligned with CE principles such as design for disassembly (DfD), material reuse, and regenerative practices refurbishment can substantially mitigate waste generation, reduce reliance on virgin resources, and support carbon reduction goals (Bimsara et al., 2024).

The design phase of refurbishment projects presents a critical opportunity for CE integration. Design decisions made at this early-stage influence material selection, construction techniques, and lifecycle performance, directly affecting sustainability outcomes (Wijewansha et al., 2021). For instance, DfD facilitates ease of deconstruction, promotes component reuse, and minimizes waste at end-of-life stages (AlJaber, Alasmari, et al., 2023). Digital tools such as Building Information Modelling (BIM) and material passports support these objectives by enhancing traceability, enabling lifecycle assessment, and informing sustainable design strategies (Leindecker et al., 2024). The deployment of such tools during the design stage allows for comprehensive resource planning and optimization.

Numerous CE frameworks and models have been proposed to guide implementation across various scales of the built environment. At the micro level (materials), meso level (buildings), and macro level (cities), frameworks like REVERT (Resource, Envisagement, Validation, Entity, Regulation, and Technology) and ReSOLVE (Regenerate, Share, Optimize, Loop, Virtualize, Exchange) facilitate multi-scale stakeholder engagement and circular transformation (Bostancı et al., 2025; Csete & Esses, 2022). The 3R (Reduce, Reuse, Recycle) and extended 9R models (including Refuse, Rethink, Repair, Refurbish, Remanufacture, and Repurpose) further provide structured approaches to resource efficiency and waste minimization (Rahla et al., 2021). Together, these frameworks support regenerative practices that preserve the value of materials and infrastructure, contributing to long-term environmental and economic sustainability.

Nonetheless, the integration of CE principles in refurbishment design remains limited, particularly in developing countries. Significant barriers persist, including regulatory ambiguities, inadequate policy enforcement, limited financial incentives, and low stakeholder awareness (AlJaber, Martinez-Vazquez, et al., 2023; Fernandes & Ferrão, 2023b). The absence of standardized documentation, weak CDW policies, and insufficient training further hinder CE adoption (Metinal & Gumusburun Ayalp, 2025). In the Sri Lankan context, outdated regulations, a lack of technological infrastructure, and minimal institutional support pose additional challenges (Athapaththu et al., 2016; Weerakoon & Thayaparan, 2023). These systemic issues result in inconsistent practices and limit practical application, even where awareness of CE benefits exists.

Despite these challenges, global and local case studies demonstrate the practical viability and advantages of CE implementation. The Grensen 9b office project in Norway, for example, achieved a 93% reduction in CO_2 emissions by integrating reused materials into its refurbishment process (Baarnes & Liang, 2025). Similarly, in Sri Lanka, University of Ruhuna, Matara, and the Ocean University Galle demonstrates how refurbishment projects have successfully applied DfD and design for adaptability (DfA) principles, achieving material circularity rates exceeding 85% through lifecycle assessment tools (De Silva et al., 2023b). These examples underscore the transformative potential of CE when incorporated at the design phase.

While existing CE frameworks offer a robust theoretical foundation, they are largely oriented towards new construction rather than refurbishment, which presents a distinct set of constraints and opportunities (Fernandes & Ferrão, 2023a). Refurbishment projects often involve existing structural limitations, non-standardized material documentation, and diverse stakeholder requirements. As such, a specialized framework is needed to facilitate systematic CE integration from the design stage in refurbishment contexts (Charef et al., 2021). Doing so can enable better resource planning, material recovery, and carbon management, ultimately contributing to a more sustainable built environment (Wijewansha et al., 2021). This study plans to design a custom approach for using circular economy standards in the design part of refurbishment projects, mainly focusing on making them more sustainable, unique, and with less waste in places like Sri Lanka and similar areas.

RESEARCH METHODOLOGY

This research aims to develop a framework for applying circular economy (CE) principles during the design phase of refurbishment projects. A qualitative literature review was conducted to explore CE's impact on sustainability, resource use, and waste management in construction. A mixed-methods approach was adopted, combining quantitative data from surveys with qualitative insights from stakeholders to assess environmental impacts and identify sustainable strategies. Purposive sampling was used to select 5–7 experienced professionals, including architects, quantity surveyors, and project managers. Structured interviews provided in-depth data. Ethical approval was secured, ensuring confidentiality and anonymity throughout the research process, in alignment with core ethical standards.

DATA COLLECTION AND ANALYSIS

Structured Interview Respondent's Profile

Interviews with construction stakeholders, including architects, quantity surveyors, and project managers, provided valuable insights into the practical challenges, opportunities, and strategies for applying circular economy (CE) principles in refurbishment design. Six structured interviews were carried out for data collection. The respondents' details were gathered through the first section of the semi-structured interview guideline. The summarized composition of respondents is presented in Table 1.

Table 32. The composition of the respondents

Interviewee	Profession	Industry Experience (Year)
Respondent 1 (R1)	Civil Engineer	10 Years
Respondent 2 (R2)	Quantity Surveyor	4 Years
Respondent 3 (R3)	Senior Cost manager	12 Years
Respondent 4 (R4)	Chartered Quantity Surveyor	30 plus Years
Respondent 5 (R5)	Client Cost Consultant and Estimator	11 Years
Respondent 6 (R6)	Charteredd Quantity Surveyor	30 Years

Thematic Analysis

The thematic analysis method is used to analyze the data gathered from structured interviews. Those selected interviewees had experience in refurbishment and were familiar with sustainable approaches, most importantly CE principles. This target group include leading quantity surveyors, cost managers and project managers doing work related to construction projects in Sri Lanka, giving the study a diverse group of perspectives. Selecting these variables in this way made sure that our data was rich, specific to the context and matched the aims of our study.

Theme 1 - Explore CE principles relevant to refurbishment projects

Expert interviews revealed both shared and unique views on the importance of CE principles in refurbishment projects. Respondents R1, R4, and R6 emphasized materials reuse, highlighting examples like rubber dust in road pavement, reused AC ducts and sanitary fittings, and steel, aluminum, and bricks. They stressed that reuse saves costs and benefits the environment, making it a practical approach in Sri Lanka. Other participants highlighted different CE aspects: R2 focused on designing out waste and pollution, reusing furniture, and durable materials; R3 emphasized adapting structures to minimize material use; and R5 pointed to design for disassembly with modular parts for less waste. These diverse perspectives show that circular refurbishment depends on multiple factors reuse, adaptability, waste reduction, and disassembly. This diversity indicates the need for flexible, combined CE training models to effectively address various principles suited to each project. Being aware of the diversity among professionals shows that a flexible and combined model of CE training is needed to address several principles fitting each case. All professionals in this study agreed that CE significantly enhances the sustainability of refurbishment projects. Respondents R2, R3, R5, and R6 emphasized CE's environmental benefits, such as reducing fresh raw material use, lowering carbon emissions, and minimizing demolition waste. They highlighted the importance of material reuse, repurposing, and life cycle thinking in improving sustainability. For instance, R2 and R3 noted CE's role in decreasing embodied carbon and extending building lifespans, while R5 shared how using similar materials in hotel renovations benefited both the environment and budget. R6 mentioned the use of renewable timber and bamboo supporting green energy.

Respondents R1 and R4 added economic, social, and procedural perspectives. R1 stressed CE's economic value in Sri Lanka, offering sustainable opportunities for young workers. R4 highlighted how organized planning and communication, like using variation orders, influence material reuse and demolition decisions. Overall, experts agreed on CE's positive sustainability impact but emphasized different aspects such as materials, carbon reduction, management, and local relevance.

Theme 2 – Analyze opportunities and issues of implementing a CE in the design stage

The interviews point out important opportunities, challenge specialists with various problems, and look at how regulations play a part in this area. The study brings out the truth about CE, illustrating how sustainable construction is done in real life with its various hurdles and rewards for people working in the industry.

Six industry experts shared common and distinct views on integrating CE principles in refurbishment design. R2, R3, and R4 emphasized material assessment and reuse, highlighting early project decisions to reduce waste and costs. They noted that involving contractors and clients early supports sustainability efforts. Meanwhile, R1 focused on financial benefits for clients and contractors, linking CE adoption to economic viability. R5 stressed designing adaptable retail and interior spaces to minimize waste during layout changes. R6 highlighted environmental priorities, advocating Life Cycle Assessment and local sourcing to lower carbon footprints and supporting regional economies. Overall, CE integration in refurbishment design balances economic, environmental, and functional considerations, with material reuse complemented by adaptability and sustainability strategies tailored to project needs.

Interviews revealed several challenges professionals face when applying CE principles in refurbishment projects. Respondents R1, R2, R3, and R6 highlighted a widespread lack of CE knowledge within companies, with both experienced leaders and younger engineers unfamiliar or hesitant to adopt it. R2 noted contractors and clients often don't understand CE's importance, while R3 pointed to outdated systems and missing guidelines limiting design flexibility. R6 emphasized skill gaps blocking successful implementation. Financial and technical barriers were also significant, as R4 observed clients' reluctance to consider higher upfront costs and Life Cycle Costing. R3 mentioned budget constraints prevent refurbishing many buildings, and R5 noted insufficient documentation complicates reuse. R6 stressed poor material traceability due to regulations and data gaps. Overall, awareness, funding, expertise, and systemic limitations challenge CE adoption in refurbishment projects.

Experts widely agree that regulatory and policy frameworks play a crucial role in supporting or hindering CE adoption in refurbishment design. R1, R3, and R4 emphasized that clear regulations and support from design bodies guide sustainable decisions early in projects. R3 highlighted rules on sustainability and waste reduction encouraging early CE integration, while R4 noted resources from the UDA promote green practices. R1 urged authorities like CIDA and ICTAD to establish consistent, strict CE policies. Conversely, R2, R5, and R6 felt current policies are insufficient, citing limited industry awareness and challenges in implementing standards like BS 8001:2017. They suggested certification programs could help but stressed the need for clearer guidelines, wider dissemination, and stronger enforcement to drive meaningful CE adoption in design processes. Table 2 below shows the expert opinion on policy influences.

Table 33: Summary of Expert responses on policy influence

Respondent	Main Viewpoint	Similar to	Key Comments
R1	Strongly supports regulatory role	R3,R4	Emphasized that professional bodies (CIDA, IESL, IQSSL) must set CE standards, particularly for quality assurance.
R2	Limited awareness, suggests certification	R5,R6	Not very aware of current CE policies; proposed that certifications (like sustainability) could help spread CE adoption.
R3	Favors mandatory CE policies	R1,R4	Stated that clear legislation and sustainability mandates push stakeholders to adopt CE from design stage.
R4	Recognizes UDA's green policy influence	R1,R3	Noted that UDA requires green practices at planning stage, making stakeholders comply early on.
R5	Policies are evolving, but not compulsory	R2,R6	Believes CE regulations in Bahrain are still informal; acknowledged green encouragement but no mandates.
R6	Weak regulatory impact in Sri Lanka	R2,R5	Highlighted limited effect of CE regulations; BS 8001 is rarely used; called for better support and collaboration.

Theme 3 – Summarize current knowledge regarding the implementation of CE

Interviews with experts revealed key strengths and challenges of current Circular Economy (CE) frameworks in refurbishment projects. Most respondents agreed that CE principles promote environmental care and reduce costs by minimizing resource use, waste, and lifecycle expenses. R4 emphasized life cycle cost analysis, while R6 highlighted benefits like lower emissions, local job creation, and use of nearby resources. R3 noted CE encourages sustainable design and innovation, and R1 mentioned longer-lasting, repairable products reduce waste. However, a major weakness is limited guidance and awareness. R1, R2, and R6 pointed to inadequate knowledge, weak training, and unclear risk-taking leading to poor implementation. R5 stressed difficulties adding CE features due to lack of data on older buildings, while R6 noted the absence of a centralized material database hinders reuse. These findings suggest CE's environmental and economic benefits are clear, but improvements in policy, education, and digital systems are necessary for effective adoption in South Asia's refurbishment sector.
Expert interviews reveal common and differing views on CE adoption in refurbishment projects. Respondents R1, R3, and R6 agree that CE use is limited and not fully established, with client willingness and awareness being key factors. R6 noted ongoing reliance on virgin materials and weak policy enforcement in Sri Lanka. R2 and R4 highlighted cost concerns, lack of knowledge, and adherence to traditional methods as barriers, often prioritizing time and budget over sustainability. R4 recommended better training to overcome reluctance and low oversight. R5 pointed out faster CE adoption in regions like Bahrain, driven by lifecycle costing and green supply chains. These findings suggest that targeted efforts, stakeholder collaboration, and institutional support are essential to expand CE implementation in refurbishment design across different contexts. Table 3 in below shows the Professionals' view on CE adoption

Table 3 Professionals' view on CE adoption

Respondent	View on CE Adoption	Key Points	Similar to
R1	**Supportive, conditional**	Willing clients and consultants essential; CE leads to savings and reduces waste	R3, R6
R2	**Skeptical, limited adoption**	CE often ignored due to cost and time pressures; reuse happens rarely; more awareness needed	R4
R3	**Optimistic, slow progress**	Adoption seen in high-profile/government projects; relies on client motivation	R1, R6
R4	**Critical, minimal adoption**	Few CE projects; traditional mindset; workers not trained for reuse	R2
R5	**Positive (International context - Bahrain)**	CE adoption growing; lifecycle costing and sustainable procurement practiced	Unique perspective
R6	**Partially aligned, systemic gaps**	Some progress via case studies; over-reliance on virgin materials; weak enforcement	R1, R3

Interviews revealed key opportunities to strengthen CE frameworks for refurbishment. R1, R2, and R3 emphasized the need to increase awareness among contractors, clients, and designers, noting this as a major barrier to CE adoption. They also suggested creating clear, separate standards to improve implementation. R4 recommended starting projects with surveys to assess recycling potential and apply CE principles early. R5 highlighted improving designers' CE knowledge at the project's outset, while R6 advocated for consistent data, training, stronger regulations, and incentives. They also noted that reusing existing buildings is more challenging than new construction, requiring careful planning. Overall, findings sow that alongside awareness and guidelines, effective CE design demands tools, education, and supportive policies for sustainable refurbishment.

Role of Digital Tools in Supporting CE Integration

Interviewees widely recognized BIM as essential for supporting CE in building renovations. Respondents R2, R3, R5, and R6 highlighted BIM's role in material tracking, lifecycle assessment, sustainable design, and collaboration. R2 noted its use for mapping materials and simulating environmental impact, while R5 applied BIM for reuse identification and facility planning. R3 praised its support for digital twins and audits, and R6 emphasized material control and greener choices. However, R1 and R4 had limited BIM knowledge, seen potential benefits but lacking expertise. This gap may hinder full CE adoption. Overall, BIM is seen as a valuable tool for circular refurbishment, but advanced training is needed for GCC construction professionals to maximize its sustainability potential.

Questionnaire Survey Respondent's Profile

We conducted a survey to see how well those in the construction industry are familiar with, recognize and make use of CE principles in their work. The survey tried to find out what various stakeholders in the construction industry thought about using CE at the design stage by blending the literature review with interviews. Table 4 shows the number of respondents received from the industry professionals through the questionnaire survey.

Table 34 Number of respondents

Professionals	Number of Participant	
	Percentage	No
Project Manager	8.70%	4
Site Engineer	10.90%	5
Civil/Structural Engineer	8.70%	4
Architect	10.90%	5
Quantity Surveyors	50%	23
Others	10.90%	5

Figure 1 shows that 82.6% of survey participants are early-career professionals with less than five years of experience. Only 14% have 6–10 years, while 2.2% each have 11–15 years and over 15 years of experience. This suggests that the survey results on CE awareness, training, and application in refurbishments may lack input from highly experienced professionals.

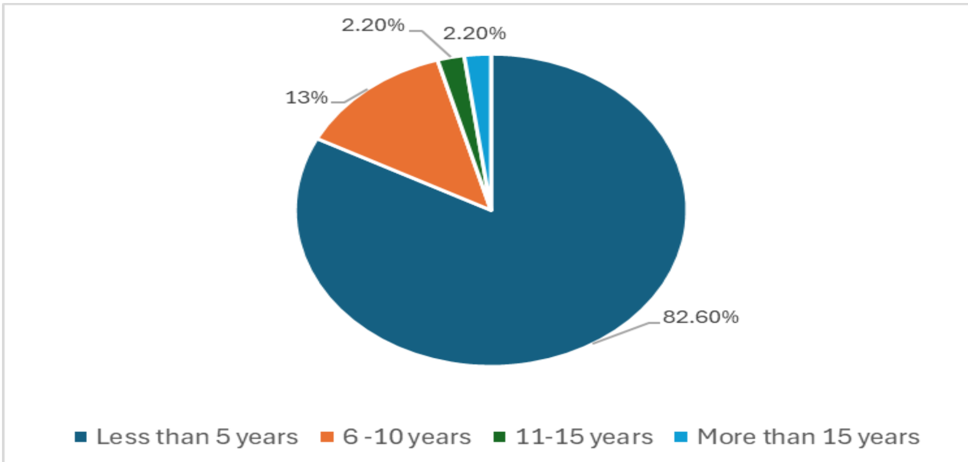


Figure 53 Experience of respondent source data analysis

Awareness and Understanding of CE Principles

Figure 2 shows the level of familiarity with CE concepts in construction.

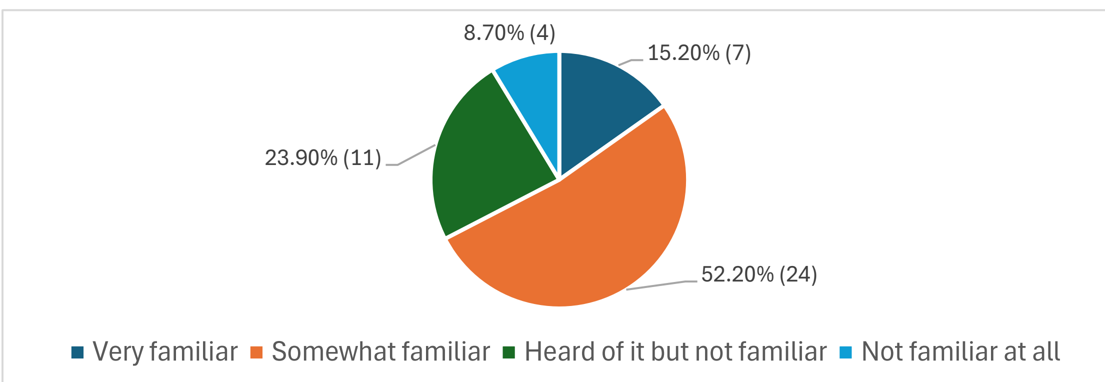
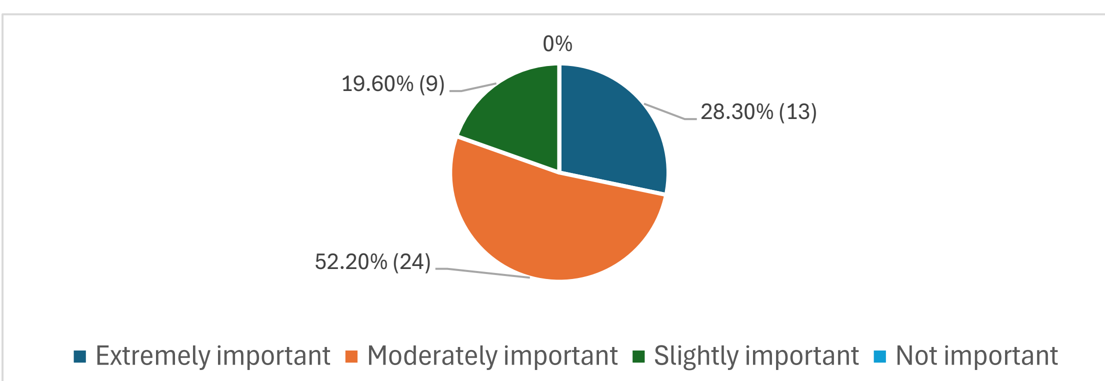


Figure 54 Awareness among participants source data analysis

Figure 3 shows the significance of integrating CE principles at the design stage.



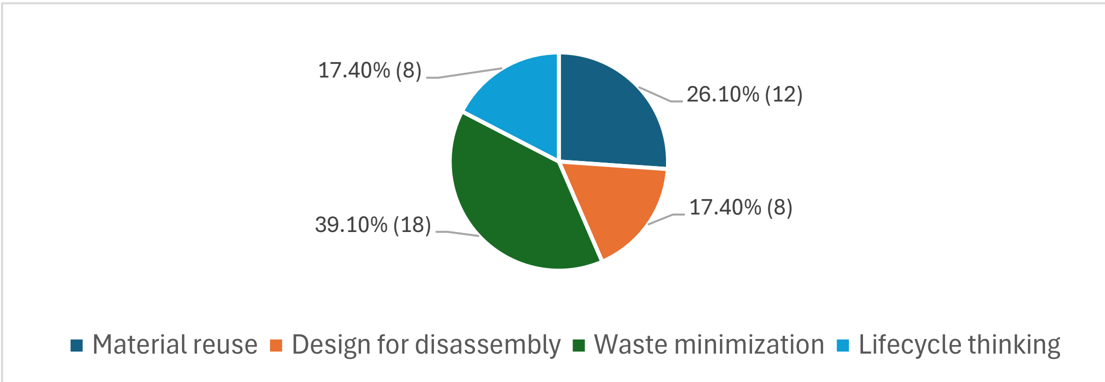


Figure 4 shows the identification of the most relevant CE principles.

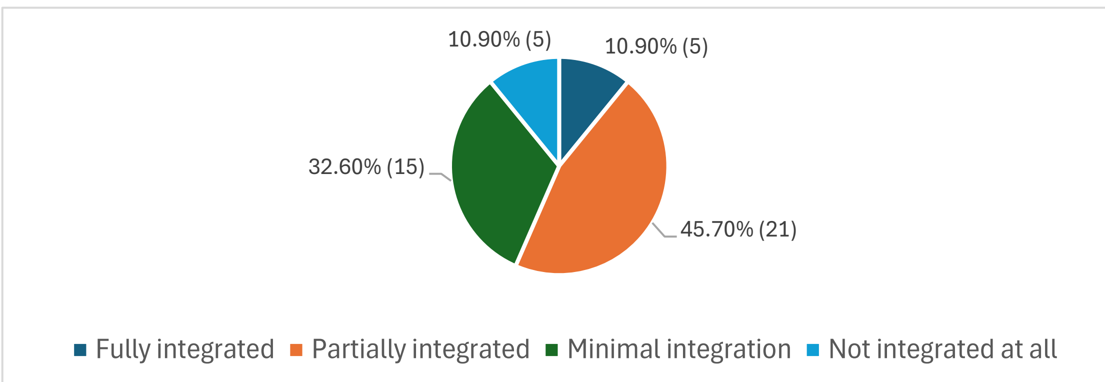


Figure 5 shows the current level of CE integration in the design phase.

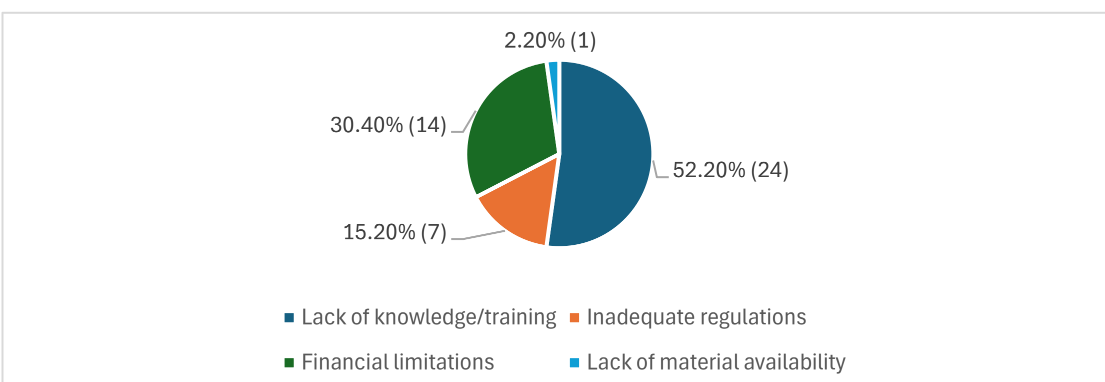


Figure 57 Current level of CE integration source data analysis

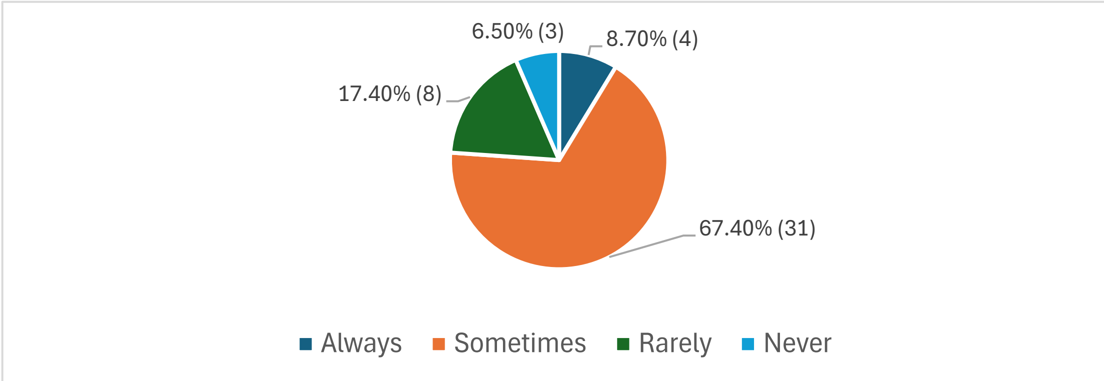


Figure 6 shows the frequency of considering DfD strategies.

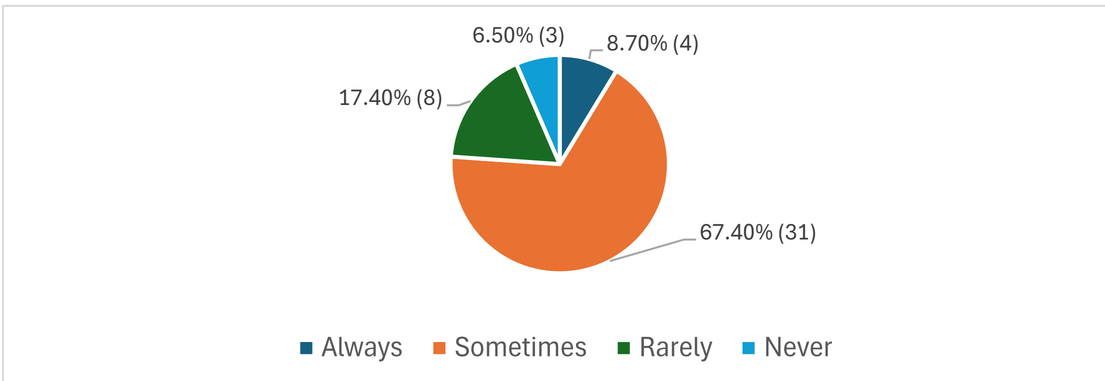


Figure 7 shows the key barriers to CE implem*entation*

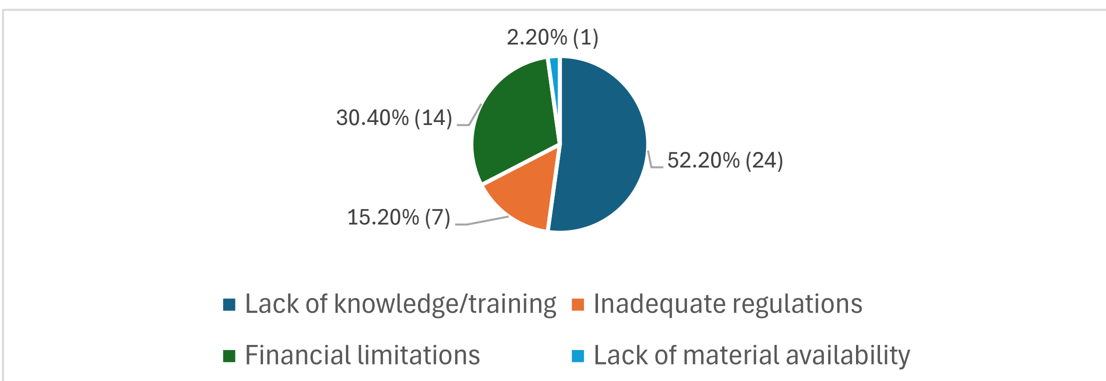


Figure 58 Barrier's source data analysis

Figure 8 shows the greatest opportunity for CE in design.

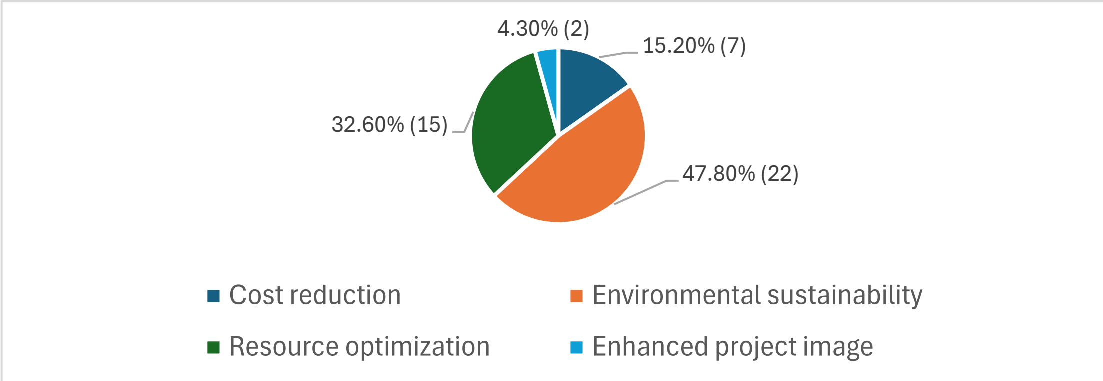


Figure 59 Opportunities source data analysis

Figure 9 shows the impact of the early design stage on the long-term sustainability of refurbishment projects.

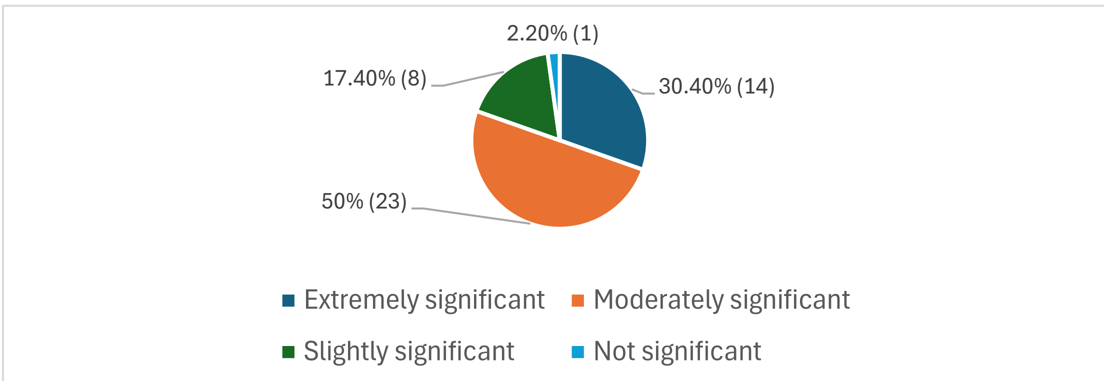


Figure 60 CE impact of early design stages on sustainability

CONCLUSION

This research successfully built a detailed Circular Economy (CE) plan designed especially for the design step in refurbishment projects based on the 2D3R rules: Design for Disassembly, Design for Adaptability, Reduce, Reuse and Recycle. It considers using sustainable methods at the start of design, so that materials can be reused and buildings adapted to live longer with less waste. Data obtained through expert interviews and survey responses revealed several key challenges and opportunities. Participants emphasized the critical importance of early-stage integration of CE strategies, including Design for Disassembly, material reuse, and lifecycle-based design approaches. Identified barriers to implementation included low stakeholder awareness, inadequate policy enforcement, limited training opportunities, and underutilization of digital tools such as Building Information Modelling (BIM). To overcome these constraints, respondents recommended targeted awareness-raising initiatives, the development of clear regulatory frameworks, incorporation of CE practices in the initial stages of design, advancement of digital competencies, and stronger collaboration among industry stakeholders. The findings underscore that effective CE integration in refurbishment projects particularly in developing contexts such as Sri Lanka requires a comprehensive approach involving technological adaptation, stakeholder engagement, and the formulation of context-sensitive regulations. In general, it guides users to include CE in rebuilding designs which supports the move from linear to circular construction. Figure 10 below shows the 2D3R framework.

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