

ADOPTION OF A CIRCULAR ECONOMY FRAMEWORK IN THE DESIGN PHASE OF THE REFURBISHMENT PROJECT

S Abilash¹, K A N Gunarathna², C. Kalugala³

Liverpool John Moores University, UK¹

Sri Lanka Institute of information Technology, SL²

Skills College of Technology, SL³

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 Reduce, Reuse, and Recycle strategies. 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 Modelling (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 Modelling, Resource efficiency*

1 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 minimizing the use 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 contemporary CE emerged 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 accounts for approximately 40% of global raw materials consumption generates 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 (Desilva 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 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 (Wijewansa et al., 2021). For instance, DfD facilitates 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 construction demolition waste policies, and insufficient training further hinder CE adoption (Metinal & Gumusburun Ayalp, 2025). In the Sri Lankan context, outdated regulations, a limited 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 CO₂ emissions by integrating reused materials into its refurbishment process (Baarnes & Liang, 2025). Similarly, in Sri Lanka, The University of Ruhuna, Matara, and the Ocean University Galle demonstrate 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 distinct 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 (Wijewansa et al., 2021). This study plans to develop a custom approach to applying circular economy standards in the design phase of refurbishment projects, primarily to make them more sustainable, unique, and less wasteful in places like Sri Lanka and similar areas.

2. 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 survey data 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.

3. DATA COLLECTION AND ANALYSIS

3.1 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 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 1: The composition of the respondents

Interviewee	Profession	Industry Experience (Years)
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)	Chartered Quantity Surveyor	30 years

3.2 Thematic Analysis

The thematic analysis method is used to analyze the data gathered from structured interviews. The selected interviewees had experience in refurbishment and were familiar with sustainable approaches, particularly CE principles. This target group includes leading quantity surveyors, cost managers and project managers working on construction projects in Sri Lanka, providing the study with a diverse set of perspectives. Selecting these variables in this way ensured that the collected data was rich, specific to the context and aligned with the aims of the study.

3.2.1 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 such as rubber dust in road pavements, reused AC ducts and sanitary fittings, and steel, aluminium, 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 using durable materials; R3 emphasized adapting structures to minimize material use; and R5 emphasized design for disassembly with modular parts to reduce 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 address various principles suited to each project effectively. Recognizing the diversity among professionals shows that a flexible and combined model of CE training is needed to address several principles that fit 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, including reduced use of fresh raw material, lower carbon emissions, and minimized demolition waste. They highlighted the importance of material reuse, repurpose, and life cycle thinking in improving sustainability. For instance, R2 and R3 noted CE's role in reducing embodied carbon and extending building lifespans, while R5 shared that using similar materials in hotel renovations benefited both the environment and the 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 well-organized planning and communication, such as use of variation orders, influence material reuse and demolition decisions. Overall, experts agreed on CE's positive sustainability impact but emphasized different aspects including materials, carbon reduction, management, and local relevance.

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

The interviewees identify important opportunities, challenge specialists with various problems, and examine how regulations play a role in this area. The study reveals the truth about CE, illustrating how sustainable construction is practiced in real life including its various hurdles and rewards for people working in 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 the importance of 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 being unfamiliar with, or hesitant to adopt it. R2 noted that contractors and clients often do not understand CE's importance, while R3 pointed to outdated systems and missing guidelines that limit 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 the poor material traceability of material 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 that current policies are insufficient, citing limited industry awareness and challenges in implementing standards such as 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 2: 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.

Source: Data: Analysis of the Expert Interviews

3.2.3 Theme 3 – Summarize current knowledge regarding the implementation of CE

Interviews with experts revealed key strengths and challenges of current 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 such as 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 the difficulties of adding CE features due to a lack of data on older buildings, while R6 noted that 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 noted faster CE adoption in regions such as 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 below shows the Professionals' views 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 show 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, seeing 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 construction professionals to maximize its sustainability potential.

3.3 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 sought to find what various stakeholders in the construction industry thought about using CE at the design stage by combining the literature review with interviews. Table 4 shows the number of respondents received from the industry professionals through the questionnaire survey.

Table 4: 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.

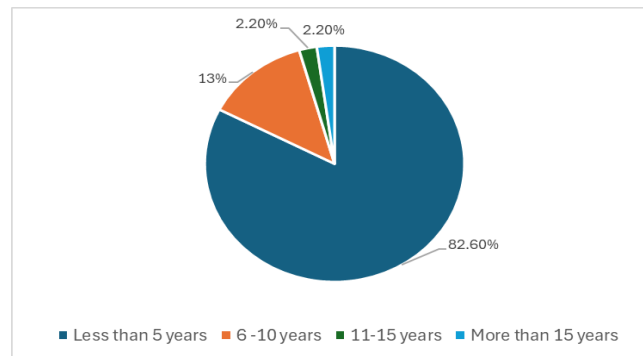


Figure 1: Experience of the Respondent
Source: Data Analysis of the Questionnaire Survey

3.3.1 Awareness and Understanding of CE Principles

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

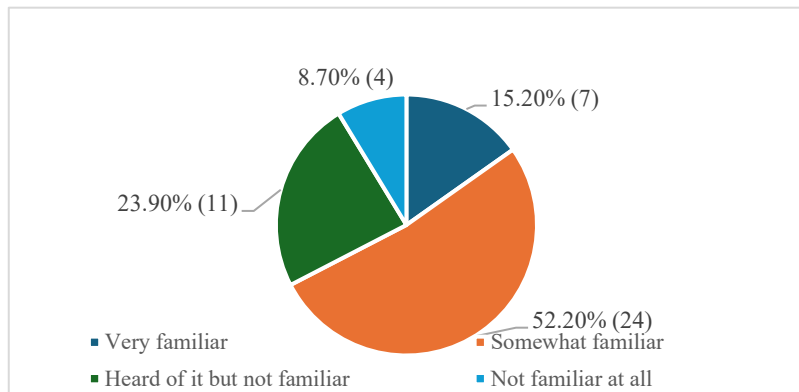
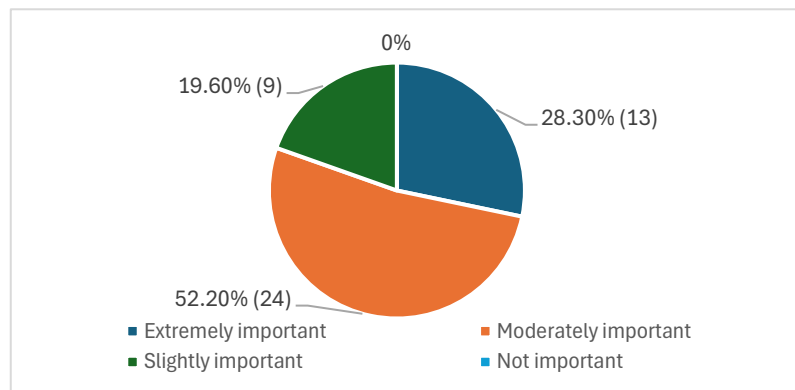


Figure 2: Awareness among Participants

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



Source: Data Analysis of the Questionnaire Survey

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

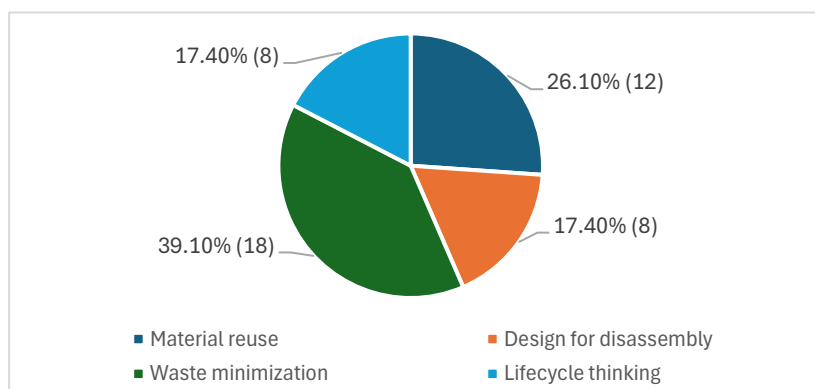


Figure 4: Identification of the most relevant CE principle

Source: Data Analysis of the Questionnaire Survey

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

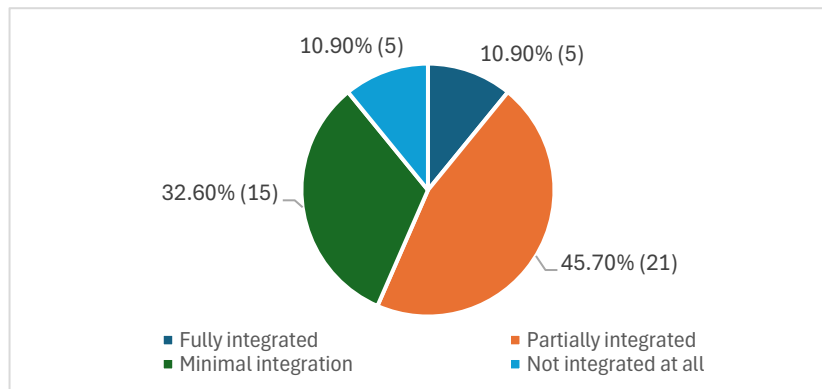


Figure 5: Current level of CE integration in the design phase
Source: Data Analysis of the Questionnaire Survey

Figure 6 shows the frequency with which DfD strategies are considered.

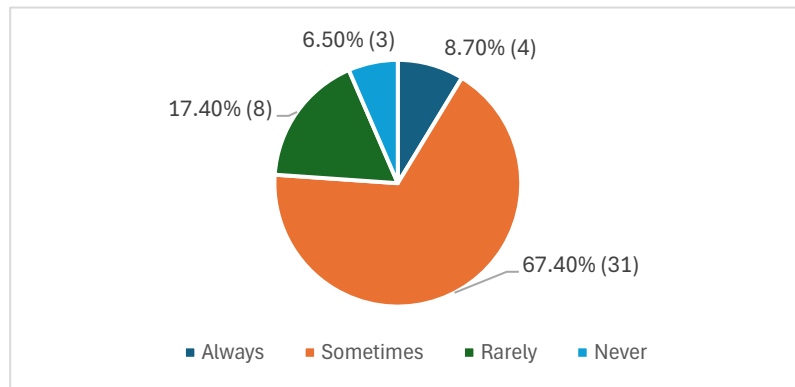


Figure 6: Frequency of considering DfD strategies
Source: Data Analysis of the Questionnaire Survey

Figure 7 shows the key barriers to CE implementation.

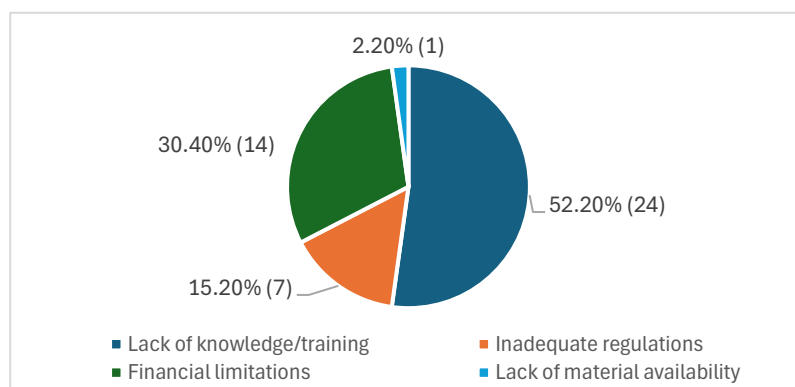


Figure 7: Key barriers to CE implementation
Source: Data Analysis of the Questionnaire Survey

Figure 8 shows the greatest opportunity for CE in design.

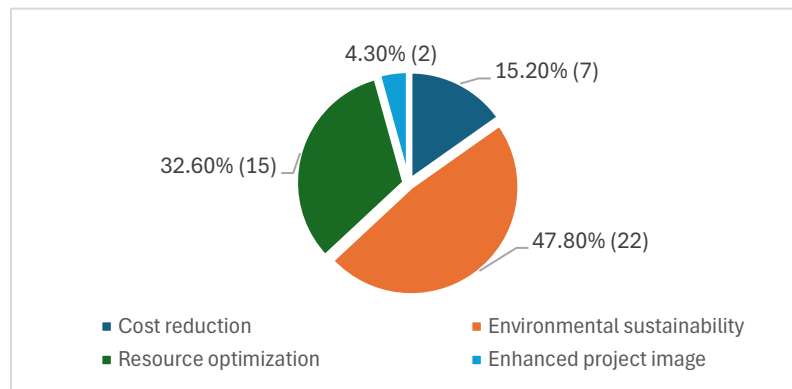


Figure 8: Greatest opportunity for CE in design
Source: Data Analysis of the Questionnaire Survey

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

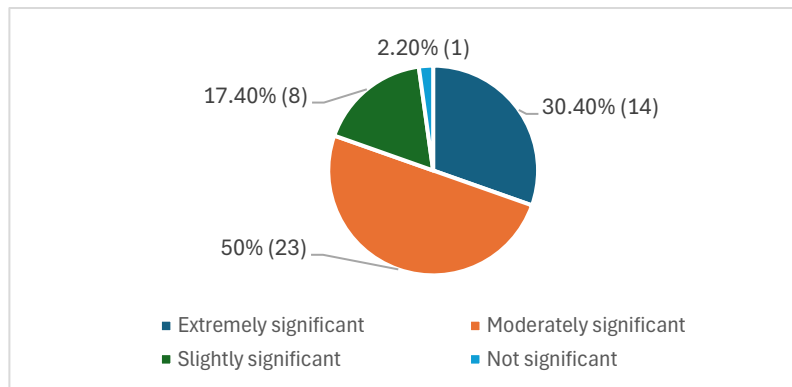


Figure 9: Impact of the early design stage on long - term sustainability
Source: Data Analysis of the Questionnaire Survey

4. CONCLUSION

This research successfully developed a detailed Circular Economy plan specifically for the design stage of 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, the incorporation of CE practices in the initial stages of design, the 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.

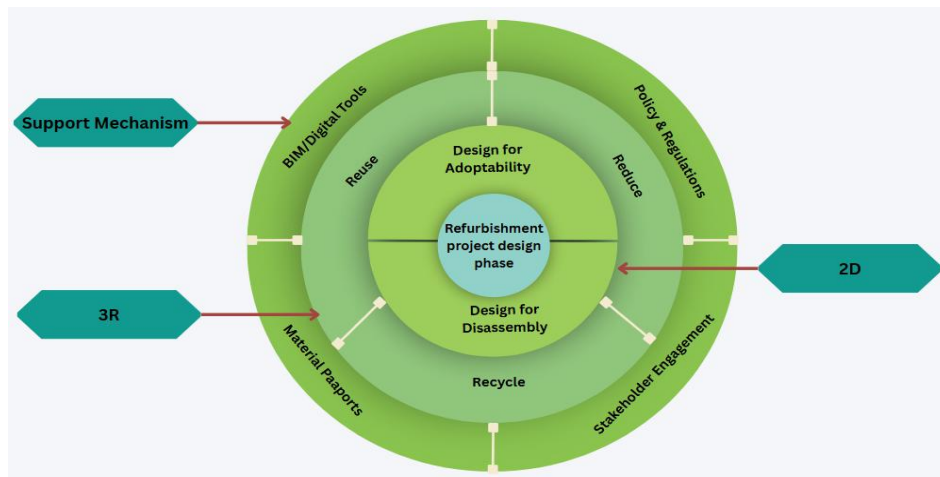


Figure 10: 2D3R Framework
Source: Data Analysis of the Questionnaire Survey

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