Circular Economy Practices in Road Rehabilitation and Development in Sri Lanka

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ABSTRACT

The integration of Circular Economy principles into road rehabilitation and development offers a sustainable alternative to traditional linear construction practices. In Sri Lanka, where road infrastructure is crucial to economic growth and connectivity, the Circular Economy offers opportunities to reduce reliance on virgin materials, minimise environmental impact, and enhance long-term cost efficiency. This study explored applicable Circular Economy strategies, assessed current implementation practices, identified key challenges, and proposed viable solutions to support Circular Economy adoption in the Sri Lankan Road sector. A mixed-methods approach was employed, combining a comprehensive literature review with data from semi-structured expert interviews and a questionnaire survey of construction professionals. The findings indicate that while awareness of the Circular Economy is growing, its practical application remains limited due to barriers such as the absence of standardized technical guidelines, insufficient government incentives, limited stakeholder knowledge, logistical challenges in material sourcing and storage, and reluctance to shift from traditional methods. Data also highlights substantial potential benefits, including cost savings, reduced construction waste, increased material efficiency, and environmental improvements. Participants emphasized the importance of pilot projects, training programs, and policy support in promoting Circular Economy practices. To overcome existing barriers, the study recommends the development of clear Circular Economy specifications, financial incentives, capacity-building initiatives, and the establishment of centralized recycling infrastructure. These strategic actions can facilitate the transition toward a more circular and sustainable approach in Sri Lanka's Road construction and maintenance sectors.

KEYWORDS: *Circular Economy, Road Construction, Road Rehabilitation, Sustainable Infrastructure, Recycled Materials*

1 INTRODUCTION

Road infrastructure development is a critical component of the development of countries, and it serves as the foundation for economic growth, social connectivity, and enhances the transport logistics system of the country (Kodithuwakku et al., 2023). The road is a legally permissible way for vehicles and other traffic to traverse. Roads include passageways, side drains, culverts and land needed for the upcoming widening (Kodithuwakku et al., 2023). Road networks include highways, expressways, urban roads, rural roads, bridges, drainage systems, and pavements, all of which play a vital role in supporting increases in the country's gross domestic product. Each of these road networks is critical to develop and maintain. The highways are designed for long-distance and high-speed travel, facilitating efficient transportation between cities, industrial zones, and ports with enabling the transportation of goods and passengers. Rural roads are essential for connecting remote areas, agricultural zones, and villages to economic centres. Effective drainage and stormwater management systems are crucial for preventing floods and road deterioration. Proper drainage infrastructure includes culverts, stormwater drains, ensuring that excess water is diverted from the road surface without disturbing road functions. The transport sector contributes 10% to 20% of the Gross Domestic Product (GDP), where road

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transportation represents between 3% to 5% of the GDP, excluding the inputs of transport equipment, fuel, and infrastructure (Kodithuwakku et al., 2023).

Traditional road rehabilitation and development are heavily based on the use of virgin materials. Conventional road construction primarily uses natural soil, crushed rock, and cement concrete in the industry. Also Bituminous materials are heavily used in road construction and the development process (Kodithuwakku et al., 2023). Bituminous materials are used as surfacing material in all types of road construction. All these materials require significant amount of energy for extraction, processing, and installation. These processes release substantial amounts of greenhouse gases, particularly carbon dioxide, into the environment and increasing global warming and contributing to climate change.

The circular economy (CE) framework offers a promising solution to reduce embodied energy in road construction and rehabilitation**.** CE emphasizes resource efficiency and waste reduction through strategies such as material reuse, recycling, and optimised design.

The global rise in construction activity, particularly in developing nations, has led to a critical shortage of high-quality natural aggregates and an increase in material costs, resulting in environmental and economic concerns (Mishra et al., 2023). Simultaneously, growing demands for more durable and resilient infrastructure have intensified pressure on traditional materials, which often fail to meet long-term performance expectations (Plati, 2019). While CE strategies offer sustainable alternatives, their adoption in road construction is hindered by high upfront costs, inadequate regulations, and logistical difficulties (Silva & Fernando, 2022). Moreover, public sector agencies face institutional limitations, such as technical gaps and fragmented policies, which restrict their ability to implement sustainable practices effectively (Connolly et al., 2023).

2 LITERATURE REVIEW

Construction of road infrastructure is one of the main aspects of a country's development and the foundation of economic development, social connectivity, and enhances the nation's transport logistics system (Kodithuwakku et al., 2023). Conventional road building uses plenty of virgin resources, including aggregates, concrete, and asphalt, and is therefore resource-intensive. These materials require large-scale extraction, processing, and transportation, which translates to a high environmental footprint and high material cost (Hammond & Jones, 2008). According to the Ellen MacArthur Foundation, CE is restorative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles (MacArthur, 2015). Benachio et al. and other authors defined CE for the construction industry as "the use of practices, in all stages of the life cycle of a building, to keep the materials as long as possible in a closed loop, to reduce the use of new natural resources in a construction project (Benachio et al., 2020).

1.1 Application of CE in Road Construction

2.1.1 Use of Recycled and Alternative Materials

CE practices promote the substitution of traditional virgin materials with recycled and alternative materials in road construction. Recycled Concrete Aggregate (RCA), derived from demolished concrete, is recognised as a viable substitute for natural aggregates in sub-base and base layers due to its self-cementing properties and high stiffness (Silva & Fernando, 2022). Crushed brick and glass, originating from construction and demolition waste, also offer utility in sub-base and asphalt applications (Kodithuwakku et al., 2023). Reclaimed Asphalt Pavement (RAP) is a key strategy to reduce the demand for virgin bitumen, lowering the embodied carbon of road infrastructure. The integration of polymer modifiers like crumb rubber further improves binder performance, reduces rutting, and supports longer pavement lifespans (Ashtiani et al., 2024). Fly ash and cement kiln dust are sustainable binders used to stabilise recycled aggregates and weak subgrades, offering economic and environmental advantages (Silva & Fernando, 2022).

2.1.2 Energy-Efficient Road Construction Methods

Energy-efficient construction practices in CE involve reducing emissions across the road's lifecycle from material extraction to end-of-life disposal. A major strategy includes the use of blended cement, where clinker is partially replaced with by-products like fly ash or slag, reducing CO_2 emissions during production (Worrell et al., 2001). Furthermore, optimising material transport through route planning and double cycling of RAP and HMA (hot mix asphalt) deliveries significantly lowers fossil fuel consumption and construction-related emissions (Kumari & Kulathunga, 2020 & Ashtiani et al., 2024). Recycling reinforced concrete waste (RCW) at the end of a road's lifecycle further conserves resources and supports circularity, providing environmental and cost benefits (Paranavithana et al., 2024).

2.1.3 Structural Performance of Recycled Materials

A major concern in CE adoption is whether recycled materials can meet structural demands. Studies have shown that pavements constructed using recycled materials can match or surpass the performance of conventional materials. For example, the inclusion of 20% RAP enhances rutting resistance and increases the stiffness of bituminous mixes, while 10% RAP improves resilient modulus from 5000 to over 6700 MPa (Silva & Fernando, 2022). RCA also improves subbase performance, with the potential to exceed 400 MPa in modulus when mixed with 25% crushed bricks. Additionally, incorporating 2% cement helps meet subbase standards under varied moisture conditions (Silva & Fernando, 2022). Fly ash is another high-performing additive for stabilising expansive soils, achieving a 26% increase in California Bearing Ratio (CBR) at a 15% mix in field tests in Melbourne. HiMA (Highly Modified Asphalt) stands out in terms of performance efficiency it allows for 20% thinner pavement layers without sacrificing structural integrity. In trials, HiMA outperformed conventional HMA in fatigue cracking and deformation under 20 million ESALs (Kluttz et al., 2017). This contributes to both material savings and lower emissions during production and transportation.

1.2 Economic Feasibility of CE in Road Development

The economic viability of CE principles in road development lies in their potential for long-term cost savings, despite initially higher investment. Sustainable pavement design emphasises longevity spanning 30 to 60 years, reducing the need for frequent maintenance, rehabilitation, and associated greenhouse gas emissions. Innovative solutions such as composite pavements and inverted asphalt layers offer high durability at lower lifecycle costs (Plati, 2019). CE-aligned techniques, such as the use of Cement Stabilised Rammed Earth, provide low-cost construction alternatives, especially suitable for resource-constrained regions (Silva & Fernando, 2022). Moreover, efficient material management can lower a substantial portion of costs attributed to materials, often exceeding 40% of total project costs, by minimising waste and leveraging recycled inputs (Kodithuwakku et al., 2023).

1.3 Policy and Regulatory Support for CE Adoption

Effective policy and regulatory frameworks are crucial for advancing CE adoption in road construction. Governments can foster circularity by setting mandatory reuse and recycling thresholds for construction projects, thereby boosting demand for secondary materials and reducing reliance on virgin resources (Ghaffar et al., 2020). Fiscal incentives and formal recognition for sustainable practices also play a pivotal role in attracting investment into CE innovations, especially those aimed at resource recovery from construction and demolition waste. Internationally, several countries have taken proactive steps. For instance, China has set a target to ensure 30% of all new buildings are prefabricated by 2026, as part of its broader CE strategy. It has also enacted policies emphasising the "reduce, reuse, recycle" principle (Li et al., 2024). Moreover, initiatives such as CERCOM (Circular Economy in Road Construction and Maintenance) project in Europe aim to institutionalise CE within national procurement frameworks. CERCOM promotes a Risk-Based Analysis Framework that evaluates technical, economic, and environmental risks associated with CE transitions, encouraging more robust and structured adoption across road infrastructure projects (Connolly et al., 2023).

1.4 Challenges to CE Implementation

Several authors have identified various types of obstacles and categorised them into six wide groups, namely social, cultural, awareness, technical, economic, and implementation. As helpful as this categorisation is, the present study shall adopt an exploratory approach, taking into consideration all possible obstacles when they emerge without restricting the inquiry to pre-defined categories (AlJaber et al., 2023).

The lack of standards for recycling and re-use is an impeding factor to the circular construction concept. Other studies also identify this lack of standards as a problem (Benachio et al., 2020). Furthermore, the lack of standardization often leads to the need for multiple costly and time-consuming certifications for alternative materials (World Green Building Council, 2023). Table 1 summarises the challenges to CE implementation.

Table 1: Challenges to CE Implementation – Summary

Challenges	**A**	**B**	**C**	**D**	**E**
High Initial/Upfront Costs	✓	✓	✓	✓	
Lack of CE Infrastructure	✓	✓			✓
Limited Knowledge and Expertise	✓	✓		✓	✓
Lack of Government Support/Incentives	✓	✓		✓	✓
Quality of Recycled Materials	✓	✓		✓	
Lack of rules and policies	✓	✓	✓		✓
Sources: (A).AlJaber et al., 2023 (B) Snigdhya et al., 2024; (C) World Green Building Council, 2023; (D) Agyemang et al., 2019; (E) Weerakoon & Thayaparan, 2023					

3 RESEARCH METHODOLOGY

With the completion of comprehensive literature review, semi-structured expert interviews were conducted to identify the challenges and barriers currently affecting the adoption of Circular Economy (CE) principles in Sri Lanka's Road construction sector. Semi-structured interviews offer a balance of flexibility and depth, making them more adaptable than structured interviews and more focused than unstructured ones. The interviews aimed to explore current CE practices, highlight implementation gaps, and capture expert perspectives on viable strategies for future integration. Subsequently, a questionnaire survey was developed based on findings from both the literature review and expert interviews. The survey was distributed among a broader group of stakeholders to validate key challenges, understand stakeholder perceptions, and evaluate the attractiveness and feasibility of CE strategies.

4 DATA COLLECTION AND ANALYSIS

4.1 Qualitative Analysis

4.1.1 Respondent's Profile

Interviews were conducted among Sri Lankan Quantity Surveyors (QSs) and engineers who are in consultancy and contractor organisations. Seven (7) semi-structured interviews were conducted for data gathering. The respondents' details were gathered through the first section of the semi-structured interview guideline. The summarized composition of respondents' profiles is presented in Table 2.

Table 2: The Composition of the Respondents

Interviewee	Designation	Experience (No. of Years)
I-01	Chartered Quantity Surveyor	8
I-02	Chartered Civil Engineer	23
I-03	Planning Engineer (civil engineer)	9
I-04	Project Manager (civil engineer)	20
I-05	Chartered Quantity Surveyor	19
I-06	Chartered Civil Engineer	24
I-07	Road Contractor	6

The semi-structured interviews conducted with professionals from Sri Lanka's Road construction sector revealed several critical insights into the existing status, challenges, and future strategies for adopting CE practices. Interviewees were drawn from government, consultancy, and contractor backgrounds, providing a comprehensive overview of the sector's position on CE.

4.1.2 Adoption of Circular Economy (CE) Practices

Expert interviews revealed that although all the participants were familiar with CE practices, their application in Sri Lankan Road construction projects remains limited. Respondents I01, I02, and I03 acknowledged awareness of CE principles but noted that actual implementation is seldom and often informal. For instance, I05 highlighted routine reuse of construction elements such as signage and milestones, while I04 provided examples where materials from demolished roads were reused as base layers in new projects. I01 also mentioned using crushed concrete in granular sub-base layers. These cases reflect a fragmented but emerging pattern of CE adoption.

4.1.3 Key Challenges in CE Implementation

Multiple challenges were identified that hinder the broader adoption of CE in road construction. The lack of technical standards and regulatory guidelines was cited by I01, I03, and I04 as the primary barrier. Engineers are reluctant to use recycled materials without standardised performance benchmarks. Moreover, I02 emphasised that both public and institutional awareness are limited, with misconceptions about the safety and durability of recycled materials. Public scepticism further hinders implementation, particularly in community-sensitive projects. Material availability and quality control were also highlighted. Interviewees I05 and I06 noted that recycled materials vary significantly in quality, and storage of materials such as RCA is logistically difficult without dedicated facilities. In addition, I01 and I05 pointed out the absence of updated testing labs, making verification of recycled material properties challenging. Resistance from stakeholders, including contractors and employers, also emerged as a theme. As I04 and I05 stated, conservative design perspectives and fear of performance issues discourage the use of alternative construction methods.

4.1.4 Current Use of Recycled and Alternative Materials

All experts confirmed using Recycled Concrete Aggregate (RCA), particularly in rural road sub-base applications. Reclaimed Asphalt Pavement (RAP) was also commonly used, especially for binder courses, as noted by I02, I04, and I06. Fly ash and cement kiln dust were used as stabilisers or filler materials in road layers, and I02 reported using quarry dust to reinforce subbase layers. Turfing reuse for drainage embankments was also mentioned. Despite these efforts, the industry faces technical and logistical constraints. Experts cited lack of design knowledge and material quality assurance, often due to inconsistent sources of recycled material and the absence of a central recycling supply chain. Approval bottlenecks, noted by I01 and I05, are frequent due to the lack of familiarity of regulatory bodies with non-conventional materials.

4.1.5 Benefits of using CE practice in Road Construction

All respondents affirmed that CE practices reduce material costs and environmental impact. The reuse of materials leads to savings in raw material procurement and reduces construction waste. I02 and I06 noted that CE improves project efficiency by saving time on material sourcing. I01 and I04 highlighted CE's contribution to long-term sustainability and raw material conservation. I05 emphasised an opportunity to develop local markets and circular supply chains, while I06 pointed to the growth of waste management industries as a secondary economic benefit.

4.1.6 Long-Term Cost Savings

All the expert interviewees strongly agreed that CE-based road construction works save considerable long-term costs, despite their comparatively greater initial investment. The consensus was based on some key economic benefits inherent in CE practices. Firstly, the reduction in raw material quarrying was mentioned as a major cost-cutting factor because CE emphasises the recycling and reuse of existing materials such as RAP and RCA, hence avoiding the expense of procuring copious amounts of virgin materials. This not only reduces procurement and transportation costs but also lowers environmental compliance expenses associated with quarrying and extraction. Secondly, it was noted by the respondents that landfill and disposal costs are significantly minimised through material recovery and reuse practices, reducing the economic and environmental cost of waste management. Also, recycling and processing of the recovered materials were described as considerably less compared to the energy and resource-intensive extraction and preparation of new materials.

4.1.7 Regulatory and Policy Needs

Government and institutional policy play a vital role in the effective implementation of CE practices in Sri Lanka's Road and infrastructure sector. I01, I02, I04, I05 and I07 indicate that there is an issue of the absence of lack of standard specification for supporting the use of recycled or alternative materials. Most existing specifications are made for use with virgin materials. Therefore, it is important to update the specifications that are relevant to use with recycling materials, as pointed out by the respondents. Also, I01, I03 and I04 noted that the introduction of Circular Procurement Policies is also crucial. They pointed out that the inclusion of CE-based Policies in Public procurement guidelines, thereby encouraging bidders to incorporate sustainable solutions. In the building construction sector, there is a standardised certification process to assess the building's environmental impact and sustainability, such as LEED and BREEM. I03, I06, and I07 mentioned that the road sector also needs such a standardised certification process to implement CE practice. Moreover, interviewees I01 and I05 emphasised that the Construction Industry Development Authority and Road Development Authority, as the primary regulatory bodies in Sri Lanka's Road Sector, should take the lead in initiating and implementing necessary policy changes to support the adoption of CE practices.

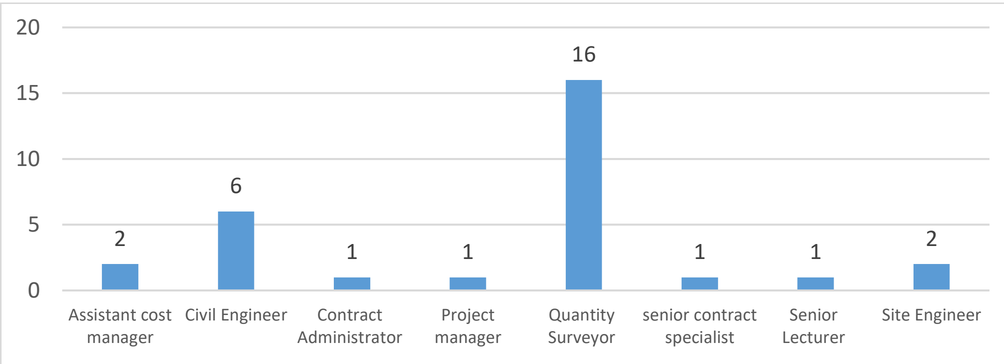
4.1.8 Financial Strategies to Support CE Implementation in Road Construction

The successful adoption of CE practices in road infrastructure projects depends not only on policy changes and technical enhancement but also on robust financial support strategies. In construction industry settings, contractors typically evaluate potential advantages and tangible benefits before adopting new construction methods. The decision to implement innovative approaches such as CE practices is often influenced by considerations of cost-efficiency. All the interviewees noted that it is important to provide tax benefits for the contractors and clients who implement CE strategies in road projects. The other widely mentioned strategy was the inclusion of CE in bid evaluation and procurement systems. Interviewees I01, I02, I05, and I06 suggested the marking criteria within tender evaluation to favour CE-compliant contractors. I02 proposed applying this, especially in Design & Build project types, which often offer flexibility in material and process selection. I05 emphasised that, as a financial strategy to implement the CE principle in road construction in BOQs, contractors can use additional preliminary items for the storage of recycling materials and recycling plants.

4.2 Quantitative Analysis

A Questionnaire Survey was distributed among forty-two (42) professionals in the construction industry, and thirty (30) responses were collected, which accounts for a response rate of 71.4%. These respondents possess hands-on experience in road projects, including consultants, project managers, quantity surveyors, civil engineers, site engineers and academics. Figure 1 illustrates a breakdown of professional categories of respondents.

Figure 1: Breakdown of Professional Categories of Respondents



Source: Quantitative data analysis

4.2.1 Circular Economy practices implemented in projects

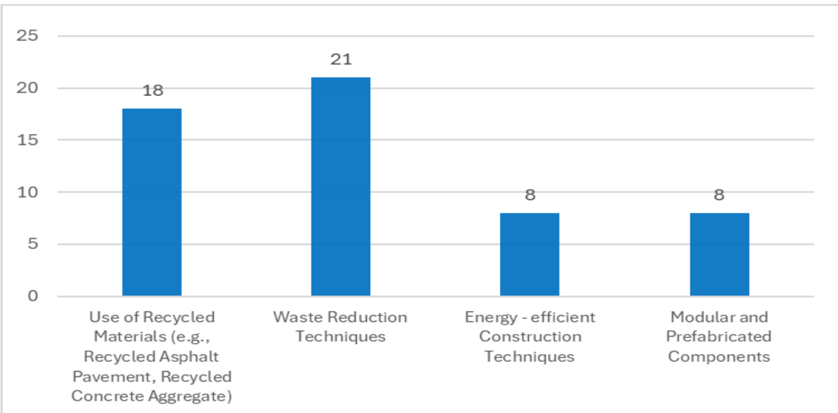


Figure 2: CE practices Implemented in Projects
Source: Quantitative data analysis

The survey results, as illustrated in Figure 2, reveal the most applied CE practice among the participants, being methods in waste reduction, by 21 participants. This is followed closely by 18 participants using recycled materials such as RAP and RCA. Fewer participants (8 participants each) reported using energy-efficient building practices and modular or prefabricated components within their activities, as another CE practice implemented.

4.2.2 Barriers faced when adopting CE practices in road development

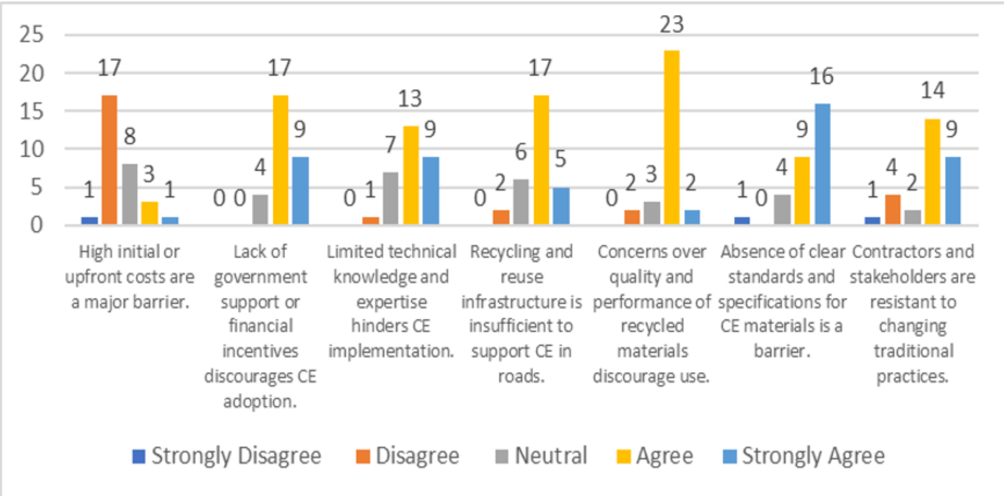


Figure 3: Barriers faced when adopting Circular Economy Practices in road development
Source: Quantitative data analysis

After conducting a thorough expert interview, these seven (7) major factors, as illustrated in Figure 3, were identified which could be challenges and barriers faced when adopting CE practices in road development. All the participants were asked to rank these factors on a Likert scale from 1 to 5 (1 being strongly disagree and 5 strongly agree) based on the magnitude of the challenges. Sixteen (16) respondents strongly agree, while nine (9) participants agree with the absence of clear standards and specifications for CE materials. Also, twenty-three (23) agree, while two (2) strongly agree, that the concerns over quality and performance of recycled materials are considered the most significant hurdles. This suggests a strong need for robust regulatory frameworks and proven performance data to build confidence in CE materials. Notably, a lack of support and financial support (17 agree) and insufficient recycling and reuse systems (17 agree, 5 strongly agree) make it difficult for CE to happen. Furthermore, the collected data were analysed and ranked by the weighted mean method using Eq. 01.

Equation 1: Weighted Factor

$$W = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i}$$

Where,

W = weighted average

N = number of terms to be averaged

ω_i = weights applied to x values

X_i = data values to be averaged

Table 3: Ranking of the Challenges

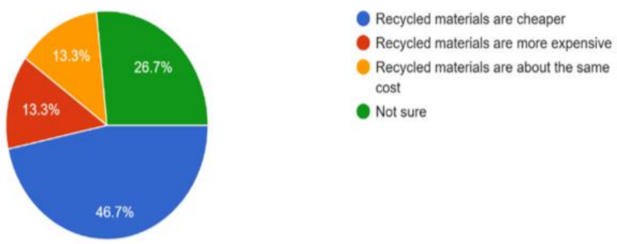
Factor	Weighted Mean	Rank
Absence of clear standards and specifications for CE materials is a barrier.	4.300	**1**
Lack of government support or financial incentives discourages CE adoption.	4.167	**2**
Limited technical knowledge and expertise hinder CE implementation.	4.000	**3**
Contractors and stakeholders are resistant to changing traditional practices.	3.867	**4**
Recycling and reuse infrastructure is insufficient to support CE in roads.	3.833	**5**
Concerns over the quality and performance of recycled materials discourage use.	3.833	**5**
High initial or upfront costs are a major barrier.	2.533	**7**

Source: Quantitative data analysis

Table 3 shows the challenges that impact while adoption of CE practices in road construction. These challenges are ranked according to the weighted mean. Accordingly, the absence of clear standards and specifications for CE materials is taken as the major barrier.

4.2.3 Cost effectiveness of using CE-based Materials

Figure 4: Cost comparison between the use of Recycled and Virgin Materials

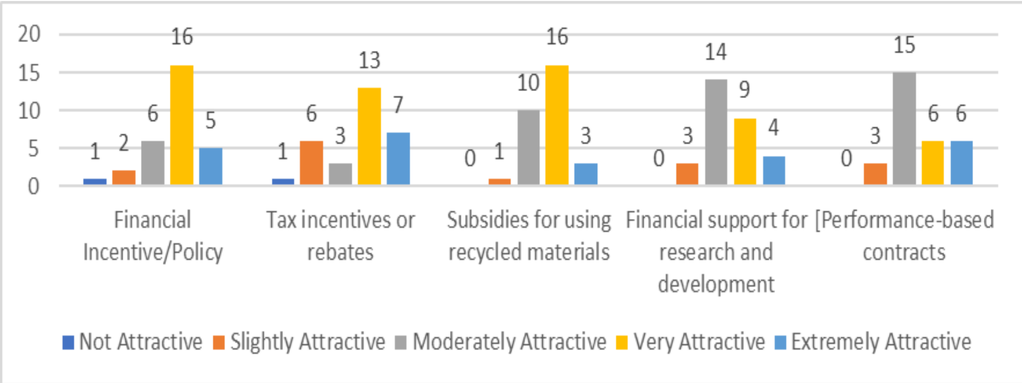


Source: Quantitative data analysis

Figure 4 shows the cost comparison between the use of recycled and virgin materials in road construction. In accordance with the data, 46.7% of respondents find recycled materials to be cheaper due to raw material extraction, transportation, and landfill disposal savings. On the contrary, 13.3% find recycled materials to be higher in cost, possibly due to extra processing, specialised equipment, or conforming to performance standards. Another 13.3% think the costs are about the same, indicating that in some cases, savings from material reuse are balanced by preparation and performance costs. Notably, 26.7% of respondents are unsure, reflecting a lack of consistent cost data or limited awareness in the industry.

4.2.4 Attractiveness of the financial incentives or policies to encourage CE practices in road construction

Figure 5: Attractiveness of Financial Incentives or Policies



Source: Quantitative data analysis

According to the questionnaire survey, financial mechanisms are essential for the adoption of the CE on Sri Lanka's roads. When respondents were asked about financial incentives and policies, the vast majority thought they were extremely attractive. Shortly afterwards, tax incentives and rebates or discounts for using recycled materials were offered, demonstrating that the industry places great significance on directly reducing costs tied to CE. Financial help for research and development, as well as results-based contracts, were appreciated but were placed lower in importance than instant financial incentives. It seems that the industry recognises innovation and quality performance, but currently it is mainly interested in ways to achieve cost savings to help CE take hold. This is clearly illustrated in Figure 5.

Table 4: Ranking of the attractiveness of financial incentives

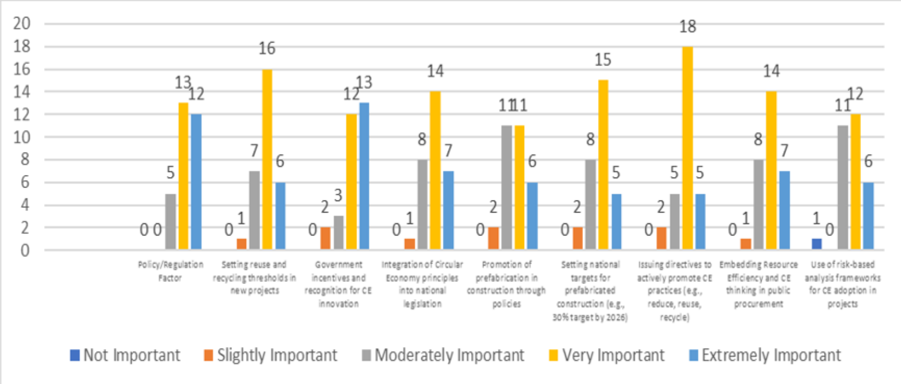
Factor	**Weighted Mean**	**Rank**
Financial Incentive/Policy	3.733	**1**
Subsidies for using recycled materials	3.700	**2**
Tax incentives or rebates	3.633	**3**
Performance-based contracts	3.500	**4**
Financial support for research and development	3.467	**5**

Source: Quantitative data analysis

Table 4 above shows the ranking of attractiveness of financial incentives or policy changes to encourage the CE principles in road construction. These enablers are ranked according to the weighted mean. Accordingly, the most attractive factor is financial incentives, and secondly, subsidies for using recycled materials.

4.2.5 Importance of the policy and regulation strategies

Figure 6: Importance of Policy and Regulation Strategies



Source: Quantitative data analysis

The stakeholder survey revealed a strong consensus on the necessity of policy and regulatory support to promote the adoption of CE practices in Sri Lanka's Road construction sector. As illustrated in Figure 6, respondents overwhelmingly rated policy interventions such as clear standards for recycling and reuse, government-backed financial incentives, and public procurement alignments "Very Important" or "Extremely Important," underscoring their critical role in driving CE integration. Notably, the establishment of recycling and reuse standards was identified as a top priority, reflecting the need for consistent technical specifications to facilitate the use of alternative materials. Similarly, financial mechanisms such as grants and tax rebates were seen as key to overcoming initial cost barriers and accelerating industry uptake. Furthermore, integrating CE principles at the planning stage was strongly endorsed, reinforcing the importance of embedding sustainability early in project lifecycles. While national targets for CE and directives aimed at waste reduction received high support, strategies such as prefabrication promotion and risk-based CE evaluation frameworks were seen as moderately important—valuable but not as central as policy and financial levers. This indicates that while technical innovations are helpful, systemic policy reform and robust institutional frameworks are viewed as the most effective catalysts for advancing CE in the road construction industry.

Table 5: Ranking of the importance of the policy and regulation strategies

Factor	Weighted mean	Rank
Policy/Regulation Factor	4.233	**1**
Government incentives and recognition for CE innovation	4.200	**2**
Setting reuse and recycling thresholds in new projects	3.900	**3**
Integration of CE principles into national legislation	3.900	**3**
Embedding Resource Efficiency and CE thinking in public procurement	3.900	**3**
Issuing directives to actively promote CE practices (e.g., reduce, reuse, recycle)	3.867	**6**
Setting national targets for prefabricated construction (e.g., 30% target by 2026)	3.767	**7**
Use of risk-based analysis frameworks for CE adoption in projects	3.733	**8**
Promotion of prefabrication in construction through policies	3.700	**9**

Source: Quantitative data analysis

The ranking results depicted in Table 5 above highlight that policy and regulatory factors are considered the most crucial drivers for adopting CE practices in road construction, with a weighted mean of 4.233. Government incentives and recognition closely follow (4.200), emphasising the importance of financial and institutional support to encourage innovation.

5 DISCUSSION

The data gathered from the literature review, semi-structured interviews, and questionnaire survey reveal that while the concept of CE is somewhat recognized in Sri Lanka's Road construction sector, its practical implementation remains limited. Both academic literature and expert insights confirm awareness of various recycled and alternative materials such as Recycled Concrete Aggregate (RCA), Reclaimed Asphalt Pavement (RAP), fly ash, cement kiln dust, crushed brick, and glass. Additionally, industry professionals highlighted the use of quarry dust, turfing for embankments, and the reuse of modular prefabricated components like curbs and signboards—demonstrating a foundational but underdeveloped application of CE practices in the sector.

5.1 Challenges and Strategic Recommendations

When integrating findings from both literature and primary data, the study proposes the following strategies to enhance CE adoption, as given in Table 7 below.

Table 7: Strategic Recommendations

Challenges	Proposed Strategies	Expected Outcome
Lack of standard specification	Updating the specification related to the road	Engineers and contractors will have clear guidelines for using recycled materials, increasing confidence and reducing reluctance.
	Incorporate alternative specs and particular specs in BOQ and tenders.	
Lack of Government Support/Incentives	Providing tax concessions for CE approaches	The industry will be financially motivated to adopt CE, overcoming the barrier of high upfront costs and encouraging innovative solutions.
	Adopt the CE approach in the bid evaluation criteria for D&B type.	
Limited Knowledge and Expertise	Training programs for contractors and suppliers on CE methods	Industry professionals will gain the necessary skills and confidence, while pilot projects will serve as practical examples and learning models.
	Make CE-based pilot projects.	
Reluctant to adopt alternative construction methods	Certification process	Stakeholders will have a formal process to validate sustainable practices, and financial incentives will encourage them to move away from traditional methods.
	Training programs for contractors and suppliers on CE methods	
	Giving tax concessions and rewards	
Availability of recycled material	Make market competition for recycled materials.	A competitive market will ensure a steady and reliable supply of recycled materials, addressing the current logistical challenges.
Storage problem	Use additional preliminary items for storage and recycling process	This will provide dedicated budget and resources for proper storage and handling, improving material quality control and logistical efficiency.

In order to effectively promote a CE in Sri Lanka's road construction sector, this research proposes a number of actionable recommendations for policymakers and practitioners. The study emphasises the urgent need for a regulatory framework, beginning with the development of clear, standardised specifications for the use of recycled and alternative materials. The findings show that without these technical standards, engineers and stakeholders are reluctant to adopt CE practices due to concerns about the quality and performance of recycled materials. Financial incentives are also critical, with a strong preference among industry professionals for **tax benefits, subsidies, and the inclusion of CE principles in bid evaluation criteria** to offset initial costs and reward sustainable approaches. Furthermore, the study suggests that the **Road Development Authority (RDA) and Construction Industry Development Authority (CIDA)** should lead the change by establishing circular procurement policies, supporting pilot projects, and promoting training programs to address the existing knowledge and expertise gaps.

The discussion reveals a substantial gap between theoretical awareness and practical application of Circular Economy practices in road construction in Sri Lanka. While literature from the global and local environment confirms the technical and financial viability of CE, ground-level implementation is hampered by regulation, institutions, and logistics. However, industry professionals demonstrate a willingness to adopt CE, provided that supportive strategies and incentives are put in place.

6 CONCLUSION

This study concludes that while the awareness of Circular Economy practices in Sri Lanka's Road construction sector is increasing, practical implementation remains limited due to key challenges such as unclear policies, lack of technical standards, limited stakeholder knowledge, and insufficient infrastructure for recycled materials. Despite these barriers, the research highlights significant potential for CE to enhance environmental sustainability, reduce construction costs, and improve long-term infrastructure performance. The findings suggest that with stronger government support, targeted policy reforms, industry training, and the development of centralised recycling systems, CE practices can be effectively integrated into road development projects. This transition will require collaborative action across public and private sectors to create a more resource-efficient and sustainable construction industry.

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REFERENCE

Agyemang, M., Kusi-Sarpong, S., Khan, S. A., Mani, V., Rehman, S. T., & Kusi-Sarpong, H. (2019). Drivers and barriers to circular economy implementation: An explorative study in Pakistan's automobile industry. *Management Decision*, *57*(4), 971–994. https://doi.org/10.1108/MD-11-2018-1178

AlJaber, A., Martinez-Vazquez, P., & Baniotopoulos, C. (2023). Barriers and Enablers to the Adoption of Circular Economy Concept in the Building Sector: A Systematic Literature Review. *Buildings*, *13*(11). https://doi.org/10.3390/buildings13112778

Ashtiani, M., Lewis, M., Waldman, B., & Simonen, K. (2024). *Strategies to Reduce Embodied Carbon in Roadway Infrastructure*.

Benachio, G., Freitas, M. do C., & Tavares, S. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *260*, 121046. https://doi.org/10.1016/j.jclepro.2020.121046

Connolly, L., Sheils, E., Lamb, M., O'Connor, A., O'Brien, E., Viner, H., Bailey, H., Ramdas, V., & Varveri, K. (2023). Circular economy in road construction and maintenance. *Transportation Research Procedia*, *72*, 3458–3465. https://doi.org/10.1016/j.trpro.2023.11.770

Ghaffar, S. H., Burman, M., & Braimah, N. (2020). Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. *Journal of Cleaner Production*, *244*, 118710. https://doi.org/10.1016/j.jclepro.2019.118710

Hammond, G. P., & Jones, C. I. (2008). Embodied energy and carbon in construction materials. *Proceedings of Institution of Civil Engineers: Energy*, *161*(2), 87–98. https://doi.org/10.1680/ener.2008.161.2.87

Kluttz, R. Q., Dongré, R., Powell, R. B., Willis, J. R., & Timm, D. H. (2017). *Long-term performance of a highly modified asphalt pavement and application to perpetual pavement design*. *June*. https://doi.org/10.14311/ee.2016.212

Kodithuwakku, H. D. D. P., Ramachandra, T., & Kajavathani, P. (2023). Alternative Materials For Sustainable Road Construction in Sri Lanka. *World Construction Symposium*, *1*, 110–122. https://doi.org/10.31705/WCS.2023.10

Kumari, T., & Kulathunga, U. (2020). *To cite this article : Thakshila Kumari, Udayangani Kulathunga, Thathsarani Hewavitharana & Nandun Madusanka (2020): Embodied carbon reduction strategies for high-rise buildings in Sri Lanka, International Journal of Construction Management, DOI : E*. https://doi.org/10.1080/15623599.2020.1814939

Li, C. Z., Tam, V. W., Lai, X., Zhou, Y., & Guo, S. (2024). Carbon footprint accounting of prefabricated buildings: A circular economy perspective. *Building and Environment*, *258*. https://doi.org/10.1016/j.buildenv.2024.111602

MacArthur, F. E. (2015). Towards a circular economy: Business rationale for an accelerated transition. *Ellen MacArthur Foundation (EMF)*, 20.

Mishra, P., Rajak, F., & Kumar, R. (2023). *Outlook of Circular Economy to High-rise Buildings Carbon Dioxide Outlook of Circular Economy to High-rise Buildings Carbon Dioxide*. *June 2024*.

Paranavithana, G. N., Samarakoon, S. M. K., & Chathurika, R. H. J. (2024). Analysis of road construction waste generation in developing economies: A focus on surfacing and sub-base construction projects in Sri Lanka. *Journal of Cleaner Production*, *457*. https://doi.org/10.1016/j.jclepro.2024.142465

Plati, C. (2019). Sustainability factors in pavement materials, design, and preservation strategies: A literature review. *Construction and Building Materials*, *211*, 539–555. https://doi.org/10.1016/j.conbuildmat.2019.03.242

Silva, S. De, & Fernando, S. (2022). *Icsbe 2022*.

Snigdhya, N. S., Uddin, S., & Dipu, A. (2024). *Integrating Climate Change Adaptation into Flood Risk Management : Global Perspectives*. *XII*(August), 1003–1012. https://doi.org/10.51244/IJRSI

Weerakoon, P., & Thayaparan, M. (2023). Analysis of Barriers Towards Implementing Circular Economy In the Sri Lankan Built Environment. *World Construction Symposium*, *1*, 162–173. https://doi.org/10.31705/WCS.2023.14

World Green Building Council. (2023). *The Circular Built Environment Playbook*. 1–97. www.worldgbc.org

Worrell, E., Price, L., Martin, N., Hendriks, C., & Meida, L. O. (2001). Carbon dioxide emissions from the global cement industry. *Annual Review of Energy and the Environment*, *26*(November), 303–329. https://doi.org/10.1146/annurev.energy.26.1.303