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Reconceptualising cost structures in construction organisations: insights for circular economy business models adoption

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Abstract

Purpose – The cost structure is a defining component in the transition towards circular economy business models (CEBMs), as construction organisations face intensifying environmental and economic pressures. However, conventional cost-driven practices still prioritise immediate financial savings. This limits the industry's ability to adopt CEBM. Hence, this study aims to examine the cost structure attributes of CEBM in construction organisations.

Design/methodology/approach – This study used an exploratory sequential mixed-methods design, combining semi-structured interviews with senior professionals and a survey of 208 respondents. This study first identified 25 cost structure attributes and then validated them through a survey and confirmatory factor analysis.

Findings – Five attributes demonstrated significant influence on CEBMs. The cost of waste handling, waste processing and remanufacturing emerged as the strongest determinants. Thus, these findings confirm that altering cost structure for CEBM adoption requires broader organisational changes and early design decisions that reduce waste at source.

Practical implications – This study advances theory by positioning cost structure as a strategic mechanism rather than a peripheral financial consideration. It provides construction organisations with evidence-based

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priorities for strengthening resource efficiency and long-term economic performance. It also provides policymakers with a clearer direction on reducing cost-related barriers to the adoption of CEBM.

Originality/value – This study presents an empirically validated approach for cost structure in CEBM for construction organisations. Hence, it advances both theoretical and practical understanding of CEBM implementation.

Keywords Business model, Circular economy, Circular economy business model, Cost structure, Construction organisations, Construction industry

Paper type Research paper

1. Introduction

The construction industry is a major consumer of natural resources and a significant contributor to environmental degradation. The industry accounts for a significant share of raw material consumption and energy use while contributing to global waste (Abdullahi *et al.*, 2023). This is because urbanisation and infrastructure demand have increased, and pressures on materials, energy and waste management have intensified. This creates urgent sustainability challenges. Traditionally, the construction industry has followed a linear "take-make-dispose" model, resulting in excessive material consumption and large volumes of construction and demolition waste. Hence, the circular economy (CE) provides a promising framework to address these challenges by retaining material value through reuse, recycling and remanufacturing. In construction, CE practices include material recovery, modular and prefabricated construction and design for adaptability, which collectively minimise waste and extend material lifecycles (Adekunle *et al.*, 2025). However, the Circular Economy Business Models (CEBMs) provide a structured approach to integrate these practices into organisational operations (Otasowie *et al.*, 2025a). It can enable construction organisations to shift from linear to circular logic, capture residual material and economic value and generate new revenue streams through refurbishment, resale and reverse logistics.

The CEBM framework comprises nine fundamental constructs that collectively support the creation, delivery and capture of circular value. Among these constructs, cost structure is particularly important because it defines the configuration and composition of cost elements required to establish, operate and sustain circular business activities. However, cost considerations often focus on immediate project expenditure, with limited attention to lifecycle impacts and residual material value in construction (Ghafoor *et al.*, 2024). Hence, the costs associated with circular practices such as design for disassembly, modular construction and reverse logistics are not fully understood within the broader CEBM context. Existing studies have examined the cost implications of individual circular strategies, including recycling, waste management and material recovery (Braakman *et al.*, 2021). Nevertheless, limited research has systematically identified, categorised and validated the cost structures that underpin CEBM implementation in construction organisations. Thus, there remains insufficient understanding of the complete cost architecture required to support circular value creation. This highlights the need for further investigation of cost structure as a fundamental CEBM construct.

This study aims to identify and validate critical attributes of the cost structure for construction organisations transitioning to CEBMs. It investigates how these attributes capture circular flows, residual material value and lifecycle benefits. Hence, this study makes a significant contribution to both theory and practice. Theoretically, it extends the CEBM literature by explicitly linking cost structures to circular flows and material value. Practically, it provides actionable guidance for project and organisational planning, strengthens the economic case for circular construction and supports informed investment decisions. This can help to promote wider adoption of CEBM in the construction industry (Otasowie *et al.*, 2025a). Also, the novelty of this study lies in its focus on cost structures as an enabler of CEBM. It addresses a gap where existing studies emphasise sustainability or isolated circular strategies without integrating financial considerations.

2. Literature review

2.1 Circular economy in the construction industry

CE has garnered increasing attention as construction activities continue to exert significant pressure on global resources. The industry consumes large volumes of raw materials and generates substantial waste. This contributes to environmental degradation and rising disposal costs. Construction and demolition waste remains one of the most significant waste streams, and rapid urbanisation intensifies the demand for new buildings and infrastructure (Alhawamdeh *et al.*, 2024). These pressures underline the need to move beyond the linear "take-make-dispose" model towards more regenerative systems. Existing studies (Smol *et al.*, 2020) explain that CE provides a framework for retaining material value through reuse, recycling and recovery. In the construction industry, strategies such as design for disassembly, modular systems, adaptable building components, material reuse and high-quality recycling are widely promoted (Adekunle *et al.*, 2025). Digital tools, including building information modeling and material passports, also support traceability and circular flows (Keles *et al.*, 2025). While these strategies are well documented, they are often described without a clear link to industry-specific business models. It is acknowledged that CE can extend material lifecycles and reduce emissions. However, the degree to which these strategies reshape organisational value creation and delivery remains contested.

Furthermore, several barriers hinder the adoption of CE. Technical challenges arise from poor documentation of existing materials, limited quality control and difficulties in disassembling buildings (Ferriz-Papi *et al.*, 2024). Economic barriers persist because many construction organisations rely on cost structures that emphasise upfront spending and short-term savings. They overlook lifecycle benefits and material residual value. Organisational barriers relate to limited skills, weak collaboration and resistance to new practices (Thirumal *et al.*, 2024). Regulatory frameworks further limit CE integration when standards and procurement rules do not support reuse or high-quality recycling. These barriers are well noted, but most studies treat them as isolated issues rather than business model issues. Similarly, CE enablers such as supportive policies, sustainable procurement practices, digital technologies and enhanced collaboration are frequently discussed. However, the analysis rarely examines how these enablers shape CEBM design in construction or influence value creation, delivery and capture in practice.

Hence, existing studies provide helpful descriptions of circular strategies, barriers and enablers. However, they focus more on isolated solutions than on the business changes necessary for CE adoption. Also, prior CEBMs are often adapted from manufacturing or general sustainability literature. This limits their relevance to the construction industry's fragmented supply chains, project-based structures and material-intensive processes. This gap shows the need for a construction-specific CEBM that addresses these unique conditions and clarifies how value can be retained across the lifecycle. Thus, this study contributes new insight to the CE literature and advances understanding of how construction organisations can operationalise CE principles more effectively through CEBM.

2.2 Circular economy business model

CEBMs provide a structured approach for organisations to integrate CE principles into their strategic and operational activities. They extend business model thinking by explaining how organisations create, deliver and capture value within circular systems. While traditional business models emphasise short-term economic returns, CEBMs prioritise long-term material value, resource flow efficiency and reduced environmental impact (Otasowie *et al.*, 2025a). This shift is crucial for construction organisations that manage resource-intensive projects and complex supply chains. CEBM frameworks commonly include nine components (Lewandowski, 2016). They are value proposition, client segments, channels, client relationships, key resources, key activities, key partnerships, cost structure and revenue streams. These components provide a useful starting point, but their application in construction raises distinct challenges.

Hence, recent studies show that CEBM has received attention in construction. Otasowie *et al.* (2025b) identified key resources necessary for CEBM adoption. These resources support visibility and recovery of material across project stages. Similarly, Otasowie *et al.* (2025c) showed that the key activities are necessary for CEBM adoption. These studies confirm that construction organisations need to operationalise circularity by redesigning resources and activities. Other studies highlight specific technical and design strategies. Nußholz *et al.* (2020) showed how secondary materials such as wood, glass and concrete can be recovered and reused in new construction products. Guerra *et al.* (2021) also highlighted design for modularity, disassembly and remanufacturing as key circular strategies in construction projects. Pekuri *et al.* (2015) further argued that business models must be grounded in operational experience to reflect real project conditions. Carra and Magdani (2017) emphasised the need for systemic thinking throughout the full construction lifecycle, while Otasowie *et al.* (2026) highlighted the importance of linking CEBM components to ensure effective implementation.

Despite these contributions, one gap remains. The cost dimension remains underdeveloped. Most studies treat costs as isolated implications rather than structured cost systems. The internal composition of cost elements in CEBM adoption is still unclear. This gap is critical because cost logic strongly influences construction decision-making. However, little empirical work explains how cost structures are formed or validated within the CEBM framework. Hence, this study extends existing work by focusing specifically on cost structures as an integrated component of CEBMs in construction organisations. It explains how cost elements interact within circular value systems and how they shape organisational adoption decisions.

2.3 Cost structure in circular economy business model

Cost structures in CEBMs in construction refer to the organised configuration of costs that arise from acquiring, deploying and coordinating resources to enable circular value creation. These structures are shaped by how organisations design, operate and recover materials and services across the project lifecycle. From a resource-based view (RBV) perspective, cost structures reflect the investments required to build and maintain circular capabilities, such as skills, infrastructure and inter-organisational partnerships (Barney, 1991). From this perspective, costs are not only expenditures, but also strategic resource commitments that enable circular performance. Recent studies on CEBMs in construction highlight value creation mechanisms such as resource recovery, product-life extension and service-based delivery models (Jayakodi *et al.*, 2024). However, these studies provide limited conceptual clarity regarding how the underlying cost structures can be formed and managed. Hence, cost structures in CEBMs extend beyond conventional construction costing systems that focus mainly on capital, labour and procurement costs (Ghafoor *et al.*, 2024). They incorporate additional cost dimensions linked to circular activities across the construction value chain.

Furthermore, using transaction cost economics (TCE), cost structures in CEBMs reflect the costs of coordination, exchange and control in circular systems (Williamson, 1985). These transaction costs emerge from activities such as reverse logistics, waste handling, material tracking, refurbishment, remanufacturing, recycling coordination and take-back systems. They also include costs associated with design for disassembly, lean construction practices, modular construction, leasing models and product-service arrangements. In addition, costs arise from collaboration among multiple stakeholders. These include contractors, suppliers, clients and recycling partners. These interactions increase the complexity of coordination and shape the entire cost structure of construction organisations. Also, these cost dimensions interact throughout the project lifecycle, influencing both short-term expenditures and long-term value capture.

It is important to note that although circular strategies may increase upfront costs, they can reduce lifecycle costs through material efficiency, reduced waste disposal and extended asset life (Braakman *et al.*, 2021). However, the current literature still lacks a clear, validated classification of cost-structure attributes specific to construction-based CEBMs. Most studies emphasise environmental benefits while under-explaining structures and cost interdependencies (Shahidi Hamedani *et al.*, 2025). Hence, a clear theoretical framing of cost structures, based on the CEBM framework (Lewandowski, 2016), is required to explain how CEBM capabilities generate and transform costs in construction organisations. This study addresses this gap by identifying and validating the cost structures that define CEBM in construction organisations. Table 1 presents the cost structure attributes derived from the literature.

3. Methodology

This study used an exploratory sequential mixed-methods approach to examine the cost structures construct in CEBMs for construction organisations. This design was appropriate because it allows researchers to explore an under-researched area qualitatively, then test and validate emerging insights quantitatively (Takona, 2024). It also aligned with the limited empirical evidence on CEBM's cost structure. Purposive sampling was adopted in the qualitative phase to select participants with strong knowledge of CE in construction. This ensured relevance but introduced selection bias, as only experienced professionals were included in the study. Participants were expected to understand CE principles, hold senior positions in construction organisations, possess academic qualifications in construction (bachelors, masters or PhD) and have experience with private and public clients. They were also required to hold managerial or supervisory roles in CE-related projects and be members of a professional body. A total of 30 professionals were invited; 15 responded, and 13 participated in the study. This number was adequate to reach saturation (Patton, 2022). Their demographic profile is shown in Table 2.

Semi-structured interviews were used because they allow flexibility and support the emergence of new insights (Kallio *et al.*, 2016). Each interview focused on identifying cost structure attributes in CEBMs for construction organisations and lasted 50–55 min via Zoom. All interviews were recorded with consent and transcribed *verbatim* using Microsoft Word to ensure accuracy (Braun and Clarke, 2022). The transcripts were analysed using content analysis with the help of the AtlasTi software. Findings from this phase and the literature review informed the design of the structured questionnaire used in the quantitative phase. The survey was piloted with five experts to check clarity and relevance (Hirshfield and Fowler, 2020). A stratified random sampling technique was used to represent South African construction organisations (grades 7–9) based on Construction Industry Development Board classifications. The total population (5,036) was divided into strata, and a sample size of 357 was calculated using Yamane's formula and proportionally allocated across strata. Respondents were randomly selected within each stratum. In total, 208 valid responses were received out of 357 questionnaires, which is sufficient for the adopted data analysis method (Bagozzi and Yi, 2012). For the quantitative data analysis, percentages were used to describe

Table 1. Cost structure attributes

Attributes	Description	Source(s)
Resource and production cost		
Cost of labour	Expenditure on the workforce required to implement and manage circular activities	Ghafoor *et al.* (2024)
Cost of resource inputs	Costs of acquiring raw, secondary or recovered materials used in production	Ghafoor *et al.* (2024)
Cost of long-lasting components	Investment in durable components designed for extended service life	Eberhardt *et al.* (2022)
Cost of producing on demand	Costs associated with producing materials or products only when required to minimise waste	Ghafoor *et al.* (2024)
Cost of lean thinking	Costs incurred in implementing lean practices to improve resource efficiency and reduce waste	Finamore and Oltean-Dumbrava (2024); Ghafoor *et al.* (2024)
Circular operations and recovery costs		
Cost of waste handling	Costs associated with collecting, sorting, storing and managing waste materials	Ghafoor *et al.* (2024)
Cost of waste processing	Costs incurred in treating waste for recovery, reuse or recycling purposes	Ghafoor *et al.* (2024)
Cost of refurbishing	Costs of restoring used products or components to a functional condition	Eberhardt *et al.* (2022)
Cost of remanufacturing	Costs of rebuilding used products or components to meet original specifications	Eberhardt *et al.* (2022)
Cost of repair	Costs associated with fixing damaged products or components to extend their lifespan	Eberhardt *et al.* (2022)
Cost of upgrading	Costs of improving existing products or components to enhance performance or usability	Ghafoor *et al.* (2024)
Cost of maintenance	Expenditure required to preserve the functionality and lifespan of assets	Torres Curado *et al.* (2024)
Material recovery and circular resource costs		
Cost of recycling components	Costs associated with converting used components into reusable materials	Ghafoor *et al.* (2024)
Cost of components upcycling	Costs of transforming used components into higher-value products	Ghafoor *et al.* (2024)
Cost of components downcycling	Costs associated with converting materials into lower-quality products	Ghafoor *et al.* (2024)
Cost of material waste reuse	Costs incurred in recovering and reusing waste materials in new applications	Ghafoor *et al.* (2024)
Cost of energy recovery	Costs associated with extracting usable energy	Lewandowski (2016)

(*continued*)

Table 1. Continued

Attributes	Description	Source(s)
Logistics and reverse supply chain costs		
Cost of transportation and logistics	Costs of moving materials, products and waste across the supply chain	Torres Curado *et al.* (2024)
Cost of take-back management	Costs associated with collecting products or materials at the end of their useful life	Ghafoor *et al.* (2024)
Cost of supply risk	Costs arising from uncertainties in material availability and quality, as well as supply chain disruptions	Finamore and Oltean-Dumbrava (2024); Torres Curado (2024)
Collaboration and CEBM costs		
Cost of facilitating collaboration	Costs associated with coordinating stakeholders involved in circular activities	Ghafoor *et al.* (2024)
Cost of client education	Costs incurred in raising client awareness and understanding of circular practices	Ghafoor *et al.* (2024)
Cost of designing out waste	Costs of incorporating waste prevention strategies during design stages	Finamore and Oltean-Dumbrava (2024)
Cost of component leasing	Costs associated with providing components through leasing arrangements rather than ownership transfer	Finamore and Oltean-Dumbrava (2024); Ghafoor *et al.* (2024)
Cost of component renting	Costs incurred in managing short-term access-based use of components	Finamore and Oltean-Dumbrava (2024); Ghafoor *et al.* (2024)

Source(s): Authors' own work

Table 2. Experts' demographics

Interviewee code	Years of experience	Class of work	Discipline/role	Highest academic qualification
E1	10	General building	Construction manager	Masters
E2	17	Civil engineering	Civil engineer	Bachelors
E3	14	Civil engineering	Civil engineer	Bachelors
E4	12	Civil engineering	Civil engineer	Bachelors
E5	16	General building	Architect	Bachelors
E6	14	General building	Architect	Masters
E7	8	General building	Architect	Masters
E8	13	Civil engineering	Civil engineer	Masters
E9	12	General building	Construction manager	Masters
E10	40	General building	Quantity surveyor	Bachelors
E11	5	General building	Construction manager	Masters
E12	11	Civil engineering	Civil engineer	Masters
E13	14	General building	Construction manager	Masters

Source(s): Authors' own work

the demographic characteristics of the survey respondents. The relative importance index (RII) was used to rank the cost structure attributes by perceived importance. This provided a clear hierarchy of cost-structure attributes within the CEBM. Also, the Kruskal–Wallis test was used to determine whether respondents' perceptions differed significantly across professional groups. This nonparametric test is appropriate for comparing opinions across three or more independent groups (Pallant, 2020). A p-value above 0.05 indicates no significant difference in perceptions among the groups, while a p-value below 0.05 indicates a statistically significant difference. Finally, confirmatory factor analysis (CFA) was used to assess the reliability and validity of the measurement items associated with the cost structure construct. The analysis was conducted using EQation software (EQS) version 6.4. A set of multidimensional model-fit indices was used to evaluate the adequacy of the measurement model. These include the root mean square error of approximation (RMSEA), Satorra–Bentler scaled chi-square (SBχ^2), standardised root mean square residual (SRMR), goodness-of-fit index (GFI) and comparative fit index (CFI). These indices provided a comprehensive assessment of the model's fit and construct validity. In addition, the Cronbach's alpha value for the cost structure construct was 0.959. Because this exceeds the recommended reliability threshold of 0.70, it demonstrates a high level of internal consistency among the measurement items. Hence, the cost structure construct used in this study is highly reliable. This confirms the questionnaire's suitability for measuring cost structure attributes and supports its effectiveness in achieving the study's objectives.

4. Results and discussion

4.1 Qualitative discussions

4.1.1 Theme 1: Resource and production costs. This dimension captures the costs of acquiring, developing and deploying resources required to support CEBM implementation. The findings reveal a broadly consistent view among respondents that resource and production-related costs form a foundational cost layer in CEBM transitions. There was strong convergence among experts that labour is one of the most significant cost drivers in CEBM adoption. E3 noted that "circular activities need skilled labour, which increases labour cost", while E6 emphasised the intensive nature of "sorting, repairing, and documenting materials”. Similarly, E9 highlighted that circular processes are more detailed and require additional labour across multiple tasks. Hence, these views suggest that labour costs extend beyond traditional construction activities to include inspection, classification, monitoring and verification tasks. This finding indicates that workforce development represents a hidden but structural cost in CEBM implementation. Unlike conventional construction labour, circular systems require multi-skilled personnel capable of handling reverse logistics and material recovery processes. This aligns with Ghafoor *et al.* (2024), who argue that circular transitions increase skill intensity and operational complexity. It also supports the RBV, positioning human capital as a critical yet costly capability in sustainability transitions. Furthermore, experts indicate that circular resource inputs currently attract higher costs than conventional materials. E1 observed that “recycled materials cost more because supply is unstable”, while E5 noted that “the price of sustainable materials is still higher than conventional alternatives”. E10 added a more optimistic view, suggesting that costs may decline as the market improves. This indicates a transitional phase in circular material markets. This divergence reflects an important tension in CEBM cost structures. On one hand, high input costs reflect immature supply systems and limited production capacity; on the other hand, experts anticipate future cost normalisation. This aligns with Ranasinghe *et al.* (2024), who note that secondary material markets are still developing and subject to price volatility. The implication is that resource input costs represent a market-formation cost, rather than a permanent structural disadvantage of circularity.

In addition, experts generally agreed that designing durable components increases upfront costs. E2 explained that “durable components cost more to manufacture”, while E5 reinforced that “high-quality materials increase the cost”. However, E10 highlighted a divergence in demand-side acceptance, noting that “clients do not always want to pay extra for durability”. This suggests a misalignment between long-term value creation and short-term procurement preferences. It indicates that long-life components introduce a front-loaded cost structure in CEBM, requiring a higher initial investment to achieve lifecycle efficiency. This finding aligns with Braakman *et al.* (2021), who argue that lifecycle benefits in circular construction are often undervalued at the procurement stage, despite long-term savings. Experts further indicate that production-on-demand models increase unit costs. E5 stated that “production on demand limits economies of scale”. This highlights reduced efficiency compared to mass production systems. It indicates that flexibility and waste reduction are achieved at the expense of traditional cost advantages. This shows that on-demand production introduces a trade-off between efficiency and circularity, in which the cost per unit increases while material waste decreases. This aligns with Lewandowski (2016), who emphasises system-level efficiency rather than unit-level cost minimisation. Thus, production-on-demand represents a structural shift in cost logic rather than a simple cost increase.

Finally, experts show that lean implementation involves significant organisational investment. E2 noted that “training staff in lean practices is costly”, while E9 emphasised that implementation requires time and planning. E11 further added that “continuous improvement activities add indirect costs”. This indicates that lean thinking introduces a capacity-building cost structure within CEBM, in which organisations must invest in training, cultural change and process redesign before efficiency gains are realised. It aligns with Ojobo *et al.* (2024), who argue that lean and circular systems are complementary but require sustained organisational commitment. From the TCE perspective, these costs also reflect coordination and adaptation efforts needed to shift from linear to circular production systems.

4.1.2 Theme 2: circular operations and recovery costs. This dimension includes costs associated with extending asset life, recovering value from products and materials and maintaining circular operational systems. Experts (E1–E9) consistently emphasised waste handling as a fundamental cost driver in CEBM implementation. A dominant view is that construction sites are not originally designed for material separation and recovery. E1 noted that "Waste handling adds significant cost because most sites are not planned for separation and temporary storage". Similarly, E4 highlighted increased operational effort, stating that organisations "spend a lot on labour and equipment just to move waste around the site". This indicates that waste handling is primarily driven by inefficiencies in site design and increased labour intensity. E9 extended this by linking costs to human resource requirements, noting that "If we want to recover materials, we need trained workers to sort them and that increases the handling cost". This suggests that waste handling is not only a logistical issue but also a capability constraint requiring skilled labour. These findings align with those of Dixit *et al.* (2022), who argued that inefficient construction logistics increase labour and equipment use in circular systems. This suggests that waste handling represents a structural inefficiency cost, arising from the mismatch between linear site planning and circular operational requirements.

Waste processing emerged as a second-order cost pressure closely linked to waste handling but extending beyond site boundaries. Experts consistently highlighted the reliance on external facilities and the fragmented nature of recycling markets. E1 explained that "Processing waste for reuse or recycling requires extra equipment and contractors". At the same time, E6 pointed to geographic inefficiencies, stating that "The cost is high because most recyclers are far from construction sites". This shows that transportation distance, limited recycling infrastructure and reliance on subcontractors increase costs. E10 added a comparative dimension, noting that "Sorting and processing waste into clean streams is still expensive compared to disposal". This introduces a key divergence in economic logic, that despite circular ambitions, landfill disposal remains the cheaper option in many countries. This supports Ghafoor *et al.* (2024), who highlight that fragmented reverse supply chains increase processing costs, and Taneepanichskul *et al.* (2022), who note that immature recycling markets distort cost competitiveness. This suggests that waste-processing costs represent a market-structure constraint, in which external system inefficiencies limit internal organisational circularity.

Furthermore, experts viewed refurbishment as a labour-intensive but value-retaining activity. E4 stated that "refurbishment needs skilled labour, and that cost is high", while E6 highlighted material variability, noting that "not all components are easy to refurbish". E10 added that refurbishment often requires hybrid interventions, explaining that "refurbishing old components often requires new parts". This suggests that refurbishment costs are driven by skill intensity and material condition. However, divergence emerges in perceived feasibility. Some experts view refurbishment as economically viable in principle but, in practice, constrained by material degradation and a lack of standardisation. This corroborates DeTroy *et al.* (2025), who argue that refurbishment depends on design for disassembly and material accessibility. It shows that refurbishment entails a condition-dependent cost structure in CEBM, in which economic viability is highly sensitive to design quality and prior use conditions.

In addition, remanufacturing was consistently identified as a promising but infrastructure-dependent cost category. E4 highlighted the core cost challenge, stating that "the cost of disassembly and refurbishment is still high". E8 emphasised systemic constraints, noting that "We lack local facilities for remanufacturing such that the cost can become higher". This indicates that the complexity of reverse logistics and limited local capacity drive remanufacturing costs. This supports Priyono *et al.* (2015), who identify disassembly, logistics and specialised facilities as cost drivers in remanufacturing systems. This suggests that remanufacturing has a scale-dependent cost structure in CEBM, in which costs decline only when supporting infrastructure, standardisation and supply chain maturity are achieved.

Similarly, repair costs were widely acknowledged across 11 experts (E1–E11). E2 noted that "Repairing components onsite takes time and skilled labour", while E5 highlighted variability, stating that "the cost varies depending on the type of component". E11 added an important nuance: "Sometimes repairs save money, but when materials are damaged, it becomes an additional cost". This introduces a clear divergence. Repair is both cost-saving and cost-increasing depending on the material's condition, accessibility and design quality. This duality aligns with Arisya and Suryantini (2021), who argue that repair efficiency depends on modularity and standardisation. This indicates that repair in CEBM involves a contingent cost structure, in which economic outcomes depend on design-for-maintenance principles and material durability (Ghafoor *et al.*, 2024).

Also, experts (E1–E13) consistently linked upgrading costs to organisational transformation requirements. E13 stated that "upgrading systems for circular economy requires new tools and technologies", while E7 noted that "upgrading facilities for reuse and repair is costly". This suggests that upgrading is capital-intensive and linked to infrastructure adaptation. However, there is divergence in perceived necessity. Some experts framed it as unavoidable for CEBM adoption, while others viewed it as a financial burden that slows the transition. This supports Otasowie *et al.* (2025a), who argue that CE adoption requires significant investment in digital and physical infrastructure. This indicates that upgrading represents a transition cost structure in CEBM, reflecting the shift from linear to circular operational systems.

Finally, maintenance costs were widely recognised as essential for extending asset life but financially burdensome in the short term. E1 stated that "Regular maintenance is essential for extending building life but comes with recurring costs". At the same time, E10 noted the temporal trade-off: "Preventive maintenance reduces failures, but it increases short-term spending". This suggests that maintenance introduces recurring operational expenditure but delivers long-term value. This reflects a clear intertemporal cost shift. These findings corroborate Ojobo *et al.* (2024), who demonstrate that preventive maintenance reduces whole-life costs despite higher upfront and recurring expenses. This indicates that maintenance represents a time-shifted cost structure in CEBM, where early expenditures enable long-term value retention and reduced lifecycle costs.

4.1.3 Theme 3: Material recovery and circular resource costs. This dimension reflects costs associated with recovering, reprocessing and transforming materials and components for continued use within CEBMs. Experts consistently highlighted recycling infrastructure as a major cost driver. E2 stated that "recycling requires processing facilities that are costly", indicating that organisations must invest in dedicated infrastructure to enable material recovery. This view reflects a strong convergence among experts, who collectively associate recycling with high upfront capital expenditure. This finding aligns with Christian *et al.* (2024), who argue that construction recycling systems require significant investment in sorting, processing and treatment facilities. It also supports the argument by Rezania *et al.* (2023) that recycling becomes economically viable only when supported by scale, policy incentives and stable supply chains.

Also, experts agreed that upcycling is a labour- and knowledge-intensive process. E13 noted that "Upcycling requires creative design and skilled labour", while E9 emphasised that "special tools and processes increase the cost". E11 further explained that the cost depends on the type of material being upcycled. This indicates the role of specialised skills and equipment in driving up the cost of upcycling, though cost predictability remains divergent, with some materials proving more economically viable than others. These findings align with Falsafi *et al.* (2025), who highlight that circular design requires advanced technical expertise and extended design time. They also support DeTroy *et al.* (2025), who note that upcycling success depends on material condition and processing complexity. This indicates that upcycling represents a high-value but uncertain cost structure in CEBM, where economic outcomes depend heavily on material quality, design capability and technological readiness. Thus, upcycling costs reflect a shift from standardised production to customised value-recovery systems.

In addition, although downcycling is often assumed to be a lower-cost recovery strategy, experts revealed that it still involves significant processing costs. E4 explained that "downcycling reduces quality, so extra treatment is needed", while E7 added that "some materials need mechanical processing, which is costly". The responses show that downcycling is neither cost-free nor simple. Instead, it involves energy-intensive mechanical processing, quality stabilisation and material conditioning. This finding aligns with Ghafoor *et al.* (2024), who argue that even low-grade material recovery requires significant processing and compliance costs. It also supports Taneepanichskul *et al.* (2022), who note that removing contamination and separating materials increases downstream costs. This suggests that downcycling functions as a cost-transformation process rather than a cost-reduction strategy, in which savings from substituting virgin materials are offset by processing and energy demands.

Furthermore, experts emphasised that converting waste into usable construction inputs entails substantial operational and quality-assurance costs. E4 stated that "processing waste into usable material is expensive", while E8 highlighted the need for equipment to convert waste streams. E10 added that quality control incurs additional costs. This suggests that reuse systems require both physical infrastructure and quality assurance mechanisms. These findings also reveal a cost shift from procurement to processing and verification stages. It aligns with Sudusinghe and Seuring (2022), who argue that circular systems redistribute costs across the value chain rather than eliminating them. This indicates that material reuse introduces a system reconfiguration cost, requiring organisations to invest in testing, processing and validation systems to ensure the performance compliance of secondary materials.

Finally, experts consistently identified energy recovery as a high-upfront investment activity. E3 stated that "energy recovery systems are expensive to set up", while E7 noted that "the technology is still new for many firms, so the cost is high". E9 added that "we see long-term benefits, but the installation cost is heavy". There is strong convergence on the capital-intensive nature of energy recovery systems and their dependence on technological maturity. However, there is also shared recognition of the long-term economic potential, despite the short-term financial burden. These findings align with Christian *et al.* (2024), who emphasised that renewable energy systems require substantial capital investment and operational expertise. Similarly, Rezania *et al.* (2023) noted that energy recovery becomes economically viable only when supported by scale efficiency and stable feedstock supply. The findings suggest that energy recovery represents a long-term investment cost structure in CEBM, where high initial capital expenditure is expected to generate future value through energy generation, cost offsetting and resource recovery.

4.1.4 Theme 4: Logistics and reverse supply chain costs. This dimension captures the costs associated with moving, collecting, coordinating and managing materials within circular supply chains. The interview findings indicate that transportation and logistics costs, take-back management costs and supply risk costs are critical elements of the cost structure in CEBM adoption. Transportation and logistics emerged as one of the most significant cost attributes within this dimension. Experts agreed that circular material flows require additional transportation activities because recovered materials are often sourced, processed and redistributed across multiple locations. E2 noted that "transporting recovered materials increases cost because the logistics are more complex", while E7 explained that "circular materials often come from different sites, so logistics become expensive". These views demonstrate the operational burden created by decentralised material flows. The findings suggest that transportation costs in CEBMs extend beyond physical movement to include planning, coordination, scheduling and tracking activities. Unlike conventional supply chains that rely on direct material delivery, circular systems involve reverse logistics processes that collect, sort, transport and reintroduce materials into the supply chain. This increases transportation distances and reduces economies of scale. Similar observations were reported by Sudusinghe and Seuring (2022), who found that circular supply chains require additional coordination mechanisms and often result in increased vehicle movements. Hence, transportation and logistics constitute a structural cost within CEBMs, as they support the circulation of materials across multiple recovery and reuse pathways.

Furthermore, experts identified take-back management as a significant cost attribute. There was broad agreement that take-back systems require substantial investment in collection, storage, monitoring and administrative activities. E1 explained that take-back schemes require storage, tracking and transport, while E5 noted that manufacturers will charge extra to operate take-back systems. These responses indicate a strong consensus that take-back programmes impose additional operational and transactional costs on construction organisations. The findings suggest that take-back systems are more than waste recovery mechanisms. They require organisations to establish reverse-flow infrastructure, develop tracking systems and coordinate the return of materials and components. This corroborates Hassan and Osman (2025), who argue that reverse supply chain systems require investments in storage facilities, inventory management systems, digital tracking technologies and contractual arrangements. Although some experts acknowledged that take-back systems may reduce disposal costs in the long term, they emphasised that the initial investment remains substantial. Hence, take-back management can be viewed as a transitional cost that supports material recovery and the retention of circular value but requires considerable upfront organisational commitment.

Finally, supply risk emerged as another important cost attribute within logistics and reverse supply chain operations. Experts highlighted the uncertainty surrounding the availability of recycled and recovered materials. E5 observed that "supply of recycled materials is inconsistent, and that risk affects cost", while E7 noted that "when the supply chain fails, we pay more to source alternatives". The convergence of these views indicates that supply instability remains a significant challenge in circular construction systems. The findings suggest that supply risk generates indirect costs through contingency planning, procurement adjustments, schedule disruptions and reliance on alternative suppliers. Unlike conventional construction materials that are sourced through established supply networks, circular materials depend on recovery rates, demolition schedules, material quality and market availability. This creates uncertainty regarding both quantity and quality. Similar findings were reported by Ghafoor *et al.* (2024), who found that instability in secondary material markets increases procurement costs and project uncertainty. The present findings extend this understanding by showing that supply risk is not merely a procurement challenge but a fundamental cost component of CEBMs. Construction organisations may be required to maintain buffer stocks, allocate contingency budgets, or procure higher-cost alternatives when recovered materials are unavailable. Hence, supply risk increases CEBMs' cost structures and may affect the financial viability of circular projects.

4.1.5 Theme 5: Collaboration and CEBM costs. The findings indicate that collaboration and CEBM-related costs represent an important dimension of the cost structure in CEBMs. Unlike traditional construction models, CEBMs require extensive coordination among multiple stakeholders. These include contractors, suppliers, recyclers, waste handlers, manufacturers and clients. Hence, organisations incur additional costs associated with collaboration, knowledge transfer, contractual arrangements and circular design practices. The experts demonstrated strong convergence regarding the cost implications of collaboration in CEBM systems. E2 explained that "working with waste handlers, recyclers, and suppliers needs coordination, and that adds cost". Similarly, E7 highlighted the need for extensive system integration, while E10 noted that "formal agreements with partners increase transaction costs". Although the experts approached the issue from different perspectives, they agreed that collaboration extends beyond normal project coordination and requires additional investments in communication, planning, monitoring and relationship management. Thus, the findings suggest that collaboration represents a significant transaction cost within CEBM implementation. From a TCE perspective, organisations incur costs when coordinating exchanges between multiple actors involved in circular value chains (Williamson, 1985). These costs arise from information sharing, contractual negotiations, performance monitoring and stakeholder alignment. This finding aligns with Jäger-Roschko and Petersen (2022), who argue that successful circular ecosystems depend on strong inter-organisational networks and shared information systems. Hence, collaboration should not be viewed solely as a relational activity but as a strategic cost structure required to support circular value creation.

Furthermore, the experts agreed on the importance of client education. E4 noted that "educating clients about circular economy takes time and resources", while E6 explained that "workshops and consultations increase project costs". E11 further observed that "some clients need repeated training". The experts recognised that many clients have limited awareness of circular practices and require continuous engagement throughout the project lifecycle. The findings suggest that client education represents a hidden but essential cost of CEBM adoption. Unlike conventional projects, circular projects often require clients to understand concepts such as material reuse, take-back systems, lifecycle value and service-based ownership models. This creates additional costs for communication, advisory and training. The findings support Alotaibi *et al.* (2024), who found that stakeholder awareness is a critical enabler of CE adoption. The results also indicate that knowledge asymmetry between project teams and clients can slow decision-making and increase implementation costs. Hence, client education functions as both a cost attribute and an investment that supports long-term CEBM adoption.

Similarly, experts demonstrated substantial agreement regarding the cost implications of designing out waste. E1 stated that "designing out waste needs more design time and analysis", while E6 observed that "we pay more for specialists who understand circular economy design". E10 further noted that "modular design adds upfront cost even though it reduces waste". The experts recognised that circular design requires additional expertise, planning and early-stage investment. Thus, the findings suggest that designing out waste shifts costs from just the construction phase to the design phase. This differs from traditional project delivery approaches, where waste management is often addressed after design decisions have been made. Circular design requires activities such as material mapping, life-cycle assessments, design for disassembly, modularisation and adaptability planning. These activities increase upfront expenditure but can generate downstream savings by reducing waste and improving resource recovery. This finding aligns with Falsafi *et al.* (2025), who argued that circular design processes are resource-intensive but fundamental to achieving long-term circular outcomes. Hence, the findings illustrate the long-term value-capture logic underpinning CEBMs.

In addition, the experts also identified component leasing as an important cost attribute. E4 explained that "leasing requires detailed contracts that add transactional cost", while E9 observed that "leasing models work, but they have hidden costs". Although experts acknowledged the benefits of leasing in extending product life and reducing ownership burdens, they also highlighted the additional administrative and contractual obligations associated with leasing arrangements. Thus, the findings suggest that leasing introduces new forms of transaction and governance costs within CEBMs. These costs arise from contract development, asset monitoring, compliance verification, liability management and performance tracking. This observation aligns with TCE, which argues that alternative ownership arrangements often require more sophisticated governance mechanisms to reduce uncertainty and opportunistic behaviour (Williamson, 1985). Hence, leasing spreads financial costs over time but simultaneously introduces ongoing management and oversight costs that must be incorporated into the cost structure.

Finally, experts recognised component renting as a distinct cost attribute. E5 explained that "renting models need tracking systems, which cost money". While there was agreement on the benefits of renting for resource efficiency and asset utilisation, experts noted that rental systems require investments in technologies and systems that enable asset circulation. Thus, the findings suggest that renting generates both technological and operational costs. Unlike traditional ownership models, renting requires organisations to continuously monitor the location, condition, availability and performance of assets. This necessitates investments in digital platforms, radio frequency identification systems, inventory management systems and asset-tracking technologies. This supports Mügge *et al.* (2024), who found that access-based business models depend heavily on digital monitoring infrastructure. Hence, although renting supports circular resource use and reduces material consumption, it also introduces additional operational and technological costs that are incorporated into the CEBM cost structure.

4.2 Quantitative respondents' demographic information

According to the responses, 3% of respondents hold a doctoral degree as their highest qualification, while 24% hold a master's degree. Furthermore, 29% of the respondents hold honours degrees, whereas 34% hold bachelor's degrees. In addition, a total of 1.9% of respondents have less than 1 year of experience in the construction industry, 6.7% of respondents have between 1 and 2 years of experience, 10.6% of respondents have between 3 and 5 years of experience, 17.3% of respondents have between 6 and 10 years of experience, 23.1% of respondents have between 11 and 15 years of experience, 12.5% of respondents have between 16 and 20 years of experience, 4.8% of respondents have between 21 and 25 years of experience and 23.1% of respondents have more than 25 years of experience in the construction industry. Hence, the research includes both entry-level professionals and experienced construction experts. Similarly, 19.2% of respondents are engineers, 17.3% are construction managers, 39.7% are architects, 19.2% are quantity surveyors and 3.9% are project managers. Thus, the research covers a diverse range of professionals within the construction industry.

4.2.1 Descriptive statistics and Kruskal-Wallis test. The results in Table 3 show that all attributes have high RII values. This implies that respondents viewed each cost structure attribute as important in CEBM cost structures. However, the *p*-values reveal where opinions differ. There is no significant difference among respondents in cost structures, with *p*-values above 0.05 for waste handling, remanufacturing and labour. This suggests that respondents

Table 3. Ranking and Kruskal–Wallis *p*-values

Label	Cost structure	Relative importance index (RII)	Kruskal–Wallis *p*-values	Rank
COS1	Cost of waste handling	0.86	0.108	1
COS2	Cost of transportation and logistics	0.84	0.004	2
COS3	Cost of refurbishing	0.84	0.018	3
COS4	Cost of waste processing	0.84	0.008	4
COS5	Cost of remanufacturing	0.84	0.114	5
COS6	Cost of labour	0.84	0.132	6
COS7	Cost of resource inputs	0.84	0.187	7
COS8	Cost of upgrading	0.84	0.039	8
COS9	Cost of repair	0.84	0.241	9
COS10	Cost of long-lasting components	0.83	<0.001	10
COS11	Cost of designing out waste	0.83	<0.001	11
COS12	Cost of maintenance	0.83	0.008	12
COS13	Cost of facilitating collaboration	0.82	0.003	13
COS14	Cost of recycling components	0.81	0.122	14
COS15	Cost of components upcycling	0.81	0.005	15
COS16	Cost of material waste reuse	0.81	0.052	16
COS17	Cost of energy recovery	0.81	0.088	17
COS18	Cost of client education	0.81	<0.001	18
COS19	Cost of producing on demand	0.80	0.013	19
COS20	Cost of take-back management	0.80	0.035	20
COS21	Cost of components downcycling	0.80	0.002	21
COS22	Cost of supply risk	0.80	0.008	22
COS23	Cost of component leasing	0.80	0.016	23
COS24	Cost of lean thinking	0.79	0.007	24
COS25	Cost of component renting	0.79	0.007	25

Source(s): Authors' own work

had similar views on these costs. Nevertheless, several attributes exhibit significant differences, as indicated by *p*-values < 0.05. These include transportation and logistics costs, refurbishment, waste processing and upgrading. Significant differences also occur for strategic or design-related costs, such as the cost of long-lasting components, designing out waste and client education. Operational attributes, such as maintenance costs, collaboration, on-demand production and take-back management, also show variation in perceptions. Hence, the results indicate that while respondents broadly agree that all cost attributes are important, their views differ mainly regarding costs associated with logistics, specialised processing, design innovation and client-related activities. This reflects the diverse operational realities of CEBM adoption in practice.

4.2.2 Confirmatory factor analysis. The CFA findings in Table 4 indicate that the cost structure measurement model provides a good fit to the data. Twenty-five variables were checked, but only COS1, COS3, COS4, COS5 and COS7 met the required threshold. The residual covariance met Byrne's requirement for symmetry around zero (Byrne, 2013). Thus, confirms model adequacy. This also aligns with the recommendations of Boomsma (2000) and Gao *et al.* (2008), who note that symmetrical residuals mitigate risks such as multicollinearity. All residual values fell within Bentler's range of −1.00 to +1.00 (Bentler, 2005), with all around zero. The average off-diagonal residual of 0.0230 was well below the limit of 2.58 (Byrne, 2013). This indicates strong measurement quality. Furthermore, the GFIs further support the model. The GFI of 0.934 and CFI of 0.950 fall within the recommended levels

Table 4. Fit indices for cost structure construct

Fit index	Cut-off value	Estimate	Comment
S-Bχ^2		18.349	
Df	x > 0.00	5	Good fit
CF1	x ≥ 0.90 acceptable x ≥ 0.95 good fit	0.950	Good fit
GFI	x ≥ 0.90 acceptable x ≥ 0.95 good fit	0.934	Acceptable
SRMR	0.08 ≥ x acceptable 0.05 ≥ x good fit	0.034	Good fit
RMSEA	0.08 ≥ x acceptable 0.05 ≥ x good fit	0.019	Good fit
NFI	x ≥ 0.90 acceptable x ≥ 0.95 good fit	0.933	Acceptable
NNFI	x ≥ 0.90 acceptable x ≥ 0.95 good fit	0.902	Acceptable
RMSEA 90% CI		0.000:0.061	Acceptable range
p-value	X > 0.05	0.00	Acceptable range

Variable	Unstandardised coefficient (λ)	Standardised coefficient (λ)	*Z*-statistics	R^2	Significant at 5% level
COS1	1.0127	0.8219	5.964	0.676	Yes
COS3	0.611	0.688	9.065	0.573	Yes
COS4	1.3635	0.8994	11.022	0.809	Yes
COS5	1.2079	0.8422	8.171	0.709	Yes
COS7	0.8012	0.7877	9.157	0.621	Yes

Variable	Factor loading	Cronbach's alpha	Rho coefficient
COS1	0.8219		
COS3	0.6880		
COS4	0.8994	0. 903	0. 909
COS5	0.8422		
COS7	0.7877		

Note(s): (S - Bχ^2) = Satorra–Bentler scaled chi-square, GFI = goodness-of-fit index, CFI = Bentler comparative fit index, SRMR = standardised root mean square residual, RMSEA = root mean square error of approximation, NFI = normed fit index, NNFI = non-normed fit index
Source(s): Authors' own work

(Iacobucci, 2010). This confirms acceptable incremental and absolute fit. The SRMR of 0.041 and the RMSEA of 0.022 are below the 0.05 threshold, indicating a good fit. The Satorra–Bentler chi-square was 18.349 (df = 5, $p = 0.000$). Although chi-square is sensitive to sample characteristics (Zhong and Yuan, 2011), the normed chi-square of 3.670 falls within the acceptable range of 3.00–5.00 (Byrne, 2013).

In addition, correlation coefficients, standard errors and *z*-values also support the measurement model's structure. All coefficients were below 1.00, showing no multicollinearity (Bentler, 2005). Each *z*-value exceeded 1.96, indicating significance at the 5% level (Hair *et al.*, 2014). All R^2 values were above 0.50. This demonstrates strong predictive power, consistent with the recommended values (Kline, 2010). Also, reliability and validity checks confirmed the construct's strength. Cronbach's alpha was 0.903, and the Rho coefficient was 0.909, both indicating high internal consistency (Kline, 2005). All factor loadings were above 0.70, except for COS3. They all exceeded the standard for convergent validity (Kline, 2005). The average variance extracted value was above 0.50. This confirms that the retained indicator variables collectively measure the construct effectively (Hair *et al.*, 2014). Hence, the results demonstrate that the measurement model is reliable, valid and statistically robust.

4.2.3 Quantitative discussion. The quantitative findings demonstrate that construction professionals perceive the cost structure of CEBMs as largely driven by operational activities related to material recovery and resource circulation. The RII results indicate that waste handling, transportation and logistics, refurbishing, waste processing, remanufacturing, labour and resource inputs are the most important cost considerations. These findings suggest that organisations transitioning towards circular construction should prioritise investments in recovery operations and reverse logistics to support effective material circulation. This finding corroborates Eberhardt *et al.* (2022), Ghafoor *et al.* (2024) and Sudusinghe and Seuring (2022), who identify resource recovery, reverse logistics and refurbishment as major cost drivers of CEBMs. However, this study extends existing knowledge by demonstrating the relative importance of these cost attributes within construction organisations.

Furthermore, the Kruskal–Wallis results enrich the findings. Several highly ranked attributes showed no significant differences in perceptions among construction professionals, particularly waste handling, remanufacturing, labour, resource inputs and repair. This indicates broad consensus among construction professionals on the importance of these costs in CEBM adoption. Such an agreement strengthens the argument that these cost categories represent the recognised challenges within circular construction. Nevertheless, significant differences emerged for transportation and logistics, refurbishing, waste processing, upgrading, designing out waste, collaboration, client education, take-back management, component leasing, lean thinking and component renting. These differences might suggest that professionals experience and manage these costs differently depending on their roles and responsibilities within construction projects. For example, project managers may be more concerned with logistics and coordination costs, while designers may place greater emphasis on design-related and lifecycle considerations.

In addition, the CFA strengthens these findings by validating the cost structure construct. The measurement model demonstrated acceptable reliability and validity. This indicates that the identified cost-structure attributes collectively constitute a coherent cost-structure construct. More importantly, the CFA results revealed that waste handling, waste processing, remanufacturing, refurbishing and resource inputs are the most significant indicators of the cost structure construct. Interestingly, four of these five attributes belong to the Circular Operations and Recovery Costs dimension, while the remaining attribute belongs to the Resource and Production Costs dimension. This clustering suggests that operational recovery activities form the core of the cost structure underpinning CEBM adoption in construction organisations. This means that construction professionals perceive the costs associated with recovering, processing and restoring materials as more influential than many of the other cost categories (Lewandowski, 2016; Ghafoor *et al.*, 2024). Hence, the quantitative findings provide empirical evidence that the cost structure of CEBMs is primarily shaped by operational recovery and material management activities. It provides a validated framework that advances existing literature on circular construction cost structures.

4.2.4 Integrated discussion. Cost structure is a fundamental component of CEBM frameworks because it determines how organisations allocate resources, manage circular activities and capture value throughout the project lifecycle (Lewandowski, 2016). Unlike conventional construction models that focus primarily on procurement, labour and disposal costs, CEBMs require organisations to account for additional costs associated with resource recovery, waste management, refurbishment, remanufacturing and circular resource flows. Hence, understanding the cost structure of the CEBM framework is essential for balancing short-term investments with long-term economic, environmental and social benefits. The study's qualitative and quantitative findings show strong convergence on the importance of cost structures in CEBM adoption. The interviews revealed that experts consistently viewed waste handling, transportation and logistics, waste processing, refurbishing, remanufacturing, labour and resource inputs as critical cost considerations. The quantitative findings support these views, as these attributes ranked among the highest-cost structure variables. This convergence suggests that construction professionals recognise that the transition to circular construction is primarily driven by operational and resource-related costs rather than by peripheral administrative activities.

Furthermore, a closer comparison of the interview findings and the quantitative results reveals that the highest-ranked attributes are concentrated within two major dimensions of the cost structure framework: Circular Operations and Recovery Costs and Logistics and Reverse Supply Chain Costs. Waste handling, waste processing, refurbishing, remanufacturing, repair, upgrading and maintenance all belong to the Circular Operations and Recovery Costs dimension. Similarly, transportation and logistics are critical components of the Logistics and Reverse Supply Chain Costs dimension. During the interviews, experts repeatedly emphasised that these activities require specialised labour, additional equipment, material-sorting systems, reverse-logistics networks and recovery infrastructure. This finding indicates that the most influential costs in CEBM adoption are directly linked to managing and recovering material flows rather than simply acquiring new resources. It also supports Ghafoor *et al.* (2024), who argue that resource recovery activities constitute the operational backbone of CEBMs.

In addition, the interviews revealed that waste handling incurs high costs because construction sites are often not designed to support material separation, temporary storage and recovery activities. The quantitative findings reinforce this view by identifying waste handling as the most important cost attribute. Similarly, respondents highlighted transportation and logistics as costly because circular material flows require moving materials between multiple locations and stakeholders. This finding is consistent with studies identifying reverse logistics as a major economic challenge in circular construction systems (Sudusinghe and Seuring, 2022). Hence, these findings suggest that organisations adopting CEBMs should invest heavily in material flow management capabilities to implement circular strategies successfully. Also, the relationship between the interview findings, RII rankings and CFA results is particularly noteworthy. Waste handling, waste processing, refurbishing, remanufacturing and resource inputs were consistently highlighted by experts during the interviews, ranked among the most important attributes in the quantitative analysis and emerged as significant indicators in the CFA model. This strong alignment across the three analytical stages strengthens the validity of the findings and suggests that these attributes constitute the foundational elements of cost structures in construction-based CEBMs. The results imply that successful circular transitions depend largely on an organisation's ability to manage costs associated with material recovery, resource circulation and operational transformation.

However, some discrepancies also emerged between the interview findings and the quantitative results. Several collaboration and CEBM-related attributes, such as facilitating collaboration, client education, designing out waste, component leasing and component renting, were discussed extensively during the interviews. Experts acknowledged that these activities require substantial investments in stakeholder engagement, coordination, knowledge sharing and contractual management. Nevertheless, these attributes ranked lower than operational and recovery-related costs in the quantitative analysis and were not retained as significant indicators in the CFA model. This suggests that construction professionals recognise the importance of collaboration and business model innovation but perceive them as secondary cost considerations compared with the immediate operational costs of waste recovery and material circulation.

Hence, the findings reveal that the cost structure of CEBMs is dominated by costs associated with resource recovery, waste management, refurbishment, remanufacturing and circular operations. The clustering of highly ranked, statistically significant attributes within the Circular Operations and Recovery Costs dimension indicates that this dimension serves as the economic core of CEBM implementation in construction organisations. Also, the importance of transportation, logistics and resource inputs underscores that circular construction extends beyond site-level activities and requires broader supply chain transformation. In addition, although collaboration, client education, leasing, renting and circular design activities remain important, they appear to serve primarily as enabling mechanisms that support the implementation of resource recovery processes rather than as primary cost drivers.

Finally, these findings extend existing literature by moving beyond isolated cost implications and demonstrating how multiple cost attributes combine to form an integrated cost structure for CEBM adoption. The results also support the RBV and TCE perspectives underpinning this study. Resource-related costs such as labour, resource inputs, upgrading and refurbishment reflect the investments required to build circular capabilities. At the same time, logistics, collaboration, take-back systems, leasing arrangements and supply risk represent transaction and coordination costs associated with managing circular value networks. Hence, the study demonstrates that cost structures in CEBMs extend beyond direct operational expenditures to include strategic investments required to establish, coordinate and sustain circular construction systems.

4.5 Implications of findings

The findings have both theoretical, practical and policy implications. Theoretically, this study contributes to the growing body of knowledge on CEBMs by providing a structured understanding of cost structures within construction organisations. Existing studies on circular construction have predominantly focused on environmental outcomes, value propositions, resource efficiency and waste reduction, while providing limited attention to the cost structures that enable circular value capture. Thus, by identifying and validating the cost structure attributes, this study extends the CEBM literature beyond isolated cost considerations and demonstrates that cost structures comprise interconnected operational, resource, logistics, recovery and collaboration-related costs. The findings also contribute to the theoretical development of CEBMs by demonstrating that cost structures are not merely financial expenditures but strategic mechanisms that support circular value creation, delivery and capture. The clustering of highly ranked attributes within the Circular Operations and Recovery Costs dimension suggests that resource recovery activities constitute the economic foundation of CEBMs in construction organisations. Furthermore, the study strengthens the application of the RBV within CEBM construction studies. The significant influence of labour, resource inputs, refurbishment, remanufacturing and upgrading costs indicates that organisations must invest in specialised capabilities, technologies, infrastructure and skills to implement CEBMs successfully. These resources create the organisational capabilities necessary for circular value creation and competitive advantage. Hence, the findings support the RBV argument that valuable organisational resources and capabilities are critical for achieving superior performance. The study also supports TCE by demonstrating that circular construction introduces additional coordination, logistics, collaboration, take-back management, leasing and supply-risk costs. These costs arise from the complex interactions required to manage circular material flows and stakeholder relationships. Hence, the study extends TCE within the CE literature by illustrating how transaction costs influence the adoption and operation of CEBMs in construction organisations.

Practically, the findings provide valuable guidance for construction organisations seeking to adopt CEBMs. The findings show that waste handling, transportation and logistics, waste processing, refurbishing, remanufacturing and resource inputs are the most influential cost considerations. Hence, construction organisations should prioritise these areas when developing CEBM strategies and investment plans. They should invest in systems that improve material recovery and resource circulation. This includes improved waste segregation systems, material-tracking technologies, reverse logistics networks and recovery infrastructure. Also, since waste handling emerged as the most influential cost attribute, organisations should focus on reducing waste generation at source through improved planning, design and site management practices. Such investments can reduce operational inefficiencies and improve long-term resource productivity. The findings also highlight the importance of developing organisational capabilities that support circular operations. Construction organisations should invest in workforce training, refurbishment expertise, remanufacturing capabilities and digital technologies that facilitate material tracking and lifecycle management. These capabilities can strengthen an organisation's ability to recover value from materials and improve the economic viability of circular initiatives. In addition, although collaboration-related costs ranked lower than operational costs, the qualitative findings demonstrate that stakeholder engagement remains essential for successful CEBM implementation. Hence, construction organisations should establish collaborative relationships with suppliers, recyclers, manufacturers, waste handlers and clients to improve resource recovery and reduce transaction costs across the circular value chain.

Finally, the findings have important implications for policymakers seeking to accelerate CE adoption within the construction industry. The findings indicate that many of the most influential cost attributes are associated with waste recovery, reverse logistics, material processing and remanufacturing activities. Hence, policymakers should develop policies that reduce the financial burden associated with these activities. Government agencies can support circular construction by investing in recycling and remanufacturing infrastructure, improving material recovery facilities and strengthening secondary material markets. Such interventions can reduce waste processing and transportation costs while improving the availability of circular resource inputs. Also, expanding circular infrastructure would enhance economies of scale and improve the commercial viability of CEBMs. The findings further suggest a need for policy instruments that encourage design for circularity. Regulatory frameworks, standards and procurement requirements should incentivise waste reduction, modular construction, design for disassembly and material reuse. Such measures can reduce downstream recovery costs and improve the efficiency of circular construction systems. In addition, public policies should support knowledge development and capacity building across the construction industry. Training programmes, professional development initiatives and industry awareness campaigns can help address capability gaps related to refurbishment, remanufacturing, circular design and resource recovery. Policymakers should also promote collaboration among industry stakeholders through sector-wide platforms and partnerships that facilitate information sharing and reduce coordination costs.

5. Conclusion

This study examined the cost structure component of CEBMs for construction organisations and showed that cost considerations play a central role in enabling circular adoption. The study began with a qualitative phase that identified 25 cost attributes, followed by a quantitative phase that ranked them and tested their influence using CFA. The findings confirm that only five attributes significantly determine the cost structure construct, with the costs of waste processing and remanufacturing being the strongest. These findings demonstrate that circular practices entail significant cost implications that construction organisations should consider when planning for transitions. Also, the study reveals that waste-related costs remain the most significant factor in shaping circular performance. This is important because early design decisions significantly impact the amount of waste generated in construction projects. Hence, the findings underscore the economic benefits of reducing waste through improved design, material selection and efficient site management. Although some circular practices require initial investment, the long-term financial, environmental and social benefits strengthen their value as strategic business decisions. The findings also show that the cost structure has a strong causal relationship with the CEBM framework. This reinforces its importance in guiding organisational strategy.

Furthermore, the study is important because it addresses a gap in CE research. The findings extend existing knowledge and position cost structure as a determinant element in circular transitions. They also contribute to global CE debates by demonstrating that economic drivers, particularly waste-related costs, are crucial for circular transformation in both developed and developing economies. Practically, the findings provide construction organisations with clear priorities. They should invest in waste reduction, recovery technologies, efficient materials and digital systems that improve tracking and reuse. These investments can reduce long-term operating costs and support sustainable value creation. In addition, the findings highlight the need for incentives that reduce the financial burden of circular practices, as well as regulations that promote waste minimisation and material efficiency at the design stage. Stronger policy support will help construction organisations overcome cost barriers and accelerate CEBM implementation. Finally, this study has some limitations. The study was conducted in South Africa. This might limit the extent to which the findings can be generalised globally. This is because the adoption of CEBMs is strongly influenced by contextual factors such as regulatory frameworks, market maturity, infrastructure availability, waste management systems, procurement practices and the level of CE development. Nevertheless, South Africa provides a valuable context for investigating CEBM adoption because it shares some characteristics with developed and developing economies. Hence, the findings may be transferable to countries with similar economic and institutional environments. The study also focused on professional perceptions, which may differ from actual organisational cost data. Hence, further studies should be conducted in other countries. Also, future studies could examine the cost data of construction organisations that have adopted CEBM.

Institutional review board statement

The study was conducted as approved by the Ethics and Plagiarism Committee (FEPC) of the Faculty of Engineering and the Built Environment at the University of Johannesburg (UJ_FEBE_FEPC_00828 and 6 June 2023).

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