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Circular Economy Strategies in the Construction Industry for Enhancing Sustainability and Reducing Environmental Impacts

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Abstract

This study aimed to systematically identify and analyze circular economy strategies in the construction industry and develop an integrated strategic framework for enhancing environmental sustainability, improving resource efficiency, and reducing waste generation through the transition from linear to circular construction systems. This research employed a qualitative systematic review design. Relevant scientific articles, policy documents, review studies, and international reports addressing circular economy implementation in the construction sector were identified and selected through a structured literature review process. The collected documents were analyzed using qualitative content analysis. Through iterative coding and thematic synthesis, major strategic categories, implementation barriers, institutional drivers, sustainability outcomes, and managerial implications associated with circular construction were identified and integrated into a comprehensive conceptual framework. The analysis revealed four major thematic dimensions governing the transition toward circular construction. First, macro-level circular strategies were classified into waste prevention, design for durability, design for disassembly, material reuse, advanced recycling, circular supply chains, digital material management, and service-based business models. Second, implementation barriers included information asymmetry, fragmented governance structures, regulatory complexity, insufficient market transparency, and limited institutional coordination, while government support, financial incentives, technological innovation, stakeholder collaboration, and public awareness emerged as key institutional drivers. Third, circular economy implementation demonstrated substantial positive effects on environmental sustainability indicators, including carbon footprint reduction, resource conservation, waste minimization, landfill diversion, improved energy efficiency, and enhanced urban environmental quality. Fourth, the synthesis of findings resulted in an integrated strategic conceptual framework in which digital infrastructure, institutional capacity, economic incentives, and technical strategies operate synergistically to facilitate circular economy adoption and long-term sustainability within the construction industry. The findings indicate that successful implementation of circular economy principles in the construction industry requires an integrated and systemic approach that combines strategic planning, supportive governance, technological innovation, economic incentives, and stakeholder collaboration. Circular construction represents not only an environmental necessity but also a strategic pathway toward sustainable resource management, enhanced competitiveness, and long-term resilience. The proposed conceptual framework provides a practical roadmap for policymakers, managers, and industry stakeholders seeking to accelerate the transition toward a sustainable and circular built environment.

Keywords: *Circular economy; Construction industry; Sustainable construction; Resource efficiency; Construction and demolition waste; Circular business models; Environmental sustainability.*

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1. Introduction

The construction industry is widely recognized as one of the most resource-intensive sectors of the global economy and simultaneously one of the largest contributors to environmental degradation. Rapid urbanization, population growth, infrastructure expansion, and increasing demand for housing have intensified pressure on natural resources and generated unprecedented quantities of construction and demolition waste. Traditional construction systems have historically been founded upon a linear economic model characterized by resource extraction, production, consumption, and disposal. Although this model has facilitated economic growth and urban development for decades, it has also produced significant environmental challenges, including excessive raw material consumption, depletion of natural resources, greenhouse gas emissions, waste accumulation, ecosystem degradation, and increased pressure on waste management systems. As concerns regarding climate change, resource scarcity, and environmental sustainability continue to grow, researchers, policymakers, and industry practitioners have increasingly recognized the necessity of transitioning from linear production systems toward more sustainable and regenerative economic models [1, 2].

Within this context, the concept of the circular economy has emerged as one of the most influential paradigms for promoting sustainable development in resource-intensive industries. The circular economy seeks to replace traditional take-make-dispose models with regenerative systems that emphasize resource efficiency, waste minimization, material recovery, reuse, recycling, and the continuous circulation of resources within economic systems. In the construction industry, the adoption of circular economy principles involves redesigning buildings, materials, supply chains, and management practices to maximize resource productivity while minimizing environmental impacts. Circular construction aims to extend the lifecycle of building materials, reduce dependence on virgin resources, and create closed-loop systems that preserve material value throughout the entire lifecycle of built assets. Consequently, the circular economy has become a strategic framework for addressing environmental, economic, and social sustainability challenges simultaneously [3, 4].

The growing importance of circular construction is reflected in the expanding body of research dedicated to sustainable resource management within the built environment. Studies have demonstrated that circular economy principles can substantially reduce construction waste, improve resource efficiency, decrease environmental burdens, and enhance long-term economic performance. Resource efficiency management has become a central concern in contemporary architecture, urban planning, and infrastructure development because inefficient resource utilization not only increases operational costs but also contributes significantly to environmental degradation. Strategic integration of circular principles within construction processes can therefore generate multiple benefits, including improved sustainability performance, reduced ecological footprints, and increased resilience of construction systems [1, 2, 5].

A key aspect of circular construction involves the adoption of strategic approaches rather than isolated technical interventions. Previous studies have argued that sustainable development in infrastructure projects requires comprehensive strategies that integrate environmental considerations into decision-making processes throughout the project lifecycle. Such strategies encompass planning, procurement, design, construction, operation, maintenance, and end-of-life management. Rather than focusing exclusively on waste treatment or recycling activities, successful circular economy implementation requires systemic transformations involving governance structures, organizational practices, regulatory frameworks, and stakeholder collaboration. Strategic planning therefore plays a critical role in facilitating the transition toward sustainable construction models capable of generating long-term environmental and economic value [3, 6, 7].

One of the most important dimensions of circular construction concerns sustainable supply chain management. Construction supply chains involve numerous stakeholders, including material suppliers, contractors, designers, developers, regulators, and end users. The complexity of these relationships often creates inefficiencies that contribute to resource waste and environmental impacts. Sustainable supply chain strategies emphasize waste prevention, material optimization, resource recovery, and collaboration among stakeholders to facilitate circular material flows. Research has demonstrated that integrating circular principles into supply chain management can significantly improve resource productivity while reducing waste generation and environmental burdens throughout construction projects [8, 9].

The successful implementation of circular economy principles also depends on the development of innovative business models capable of aligning economic incentives with sustainability objectives. Traditional business models within the construction industry often prioritize short-term financial performance and linear material consumption patterns. In contrast, circular business models focus on value retention, resource recovery, product-service systems, leasing arrangements, refurbishment, remanufacturing, and material reuse. These approaches seek to maximize the utility and lifespan of resources while creating new economic opportunities within the construction sector. Recent studies have highlighted the growing importance of service-based business models as mechanisms for facilitating circularity, although significant organizational, legal, and financial barriers continue to hinder their widespread adoption [10-12].

Technological innovation represents another critical driver of circular economy implementation in the construction industry. Emerging technologies have expanded opportunities for material recovery, recycling, lifecycle assessment, digital monitoring, and resource optimization. Advanced recycling systems, material tracking technologies, and digital construction platforms have improved the feasibility of implementing circular strategies across complex construction projects. European experiences have demonstrated the strategic importance of technological innovation in enhancing waste recycling efficiency and supporting circular construction objectives. Consequently, technology development has become a central component of contemporary sustainability strategies within the built environment [13, 14].

Digitalization has further transformed the potential for circular economy implementation by enabling more sophisticated approaches to resource management and lifecycle monitoring. Building Information Modeling (BIM), digital twins, material passports, and integrated information systems provide new opportunities for tracking material flows, facilitating reuse, and optimizing resource utilization. Digital technologies improve transparency throughout the construction lifecycle and support informed decision-making regarding material selection, maintenance, refurbishment, and end-of-life management. Researchers have emphasized that digital transformation is increasingly essential for creating circular value chains capable of supporting sustainable construction practices at scale [15-17].

Despite these opportunities, numerous barriers continue to impede the transition toward circular construction systems. Information asymmetry remains one of the most persistent challenges affecting secondary material markets and resource recovery initiatives. In many cases, stakeholders lack reliable information regarding material quality, availability, traceability, and potential reuse opportunities. This uncertainty reduces confidence in secondary materials and limits market development. Recent studies have suggested that digital solutions and information-sharing platforms can help overcome these challenges by enhancing transparency and facilitating stakeholder collaboration [18, 19].

Institutional and regulatory factors also play a crucial role in determining the success of circular economy initiatives. Administrative bureaucracy, fragmented governance structures, inconsistent regulations, and inadequate policy support frequently create obstacles to circular construction implementation. The construction industry often operates within institutional environments designed around linear economic assumptions, making it difficult to integrate innovative circular practices. Comparative analyses have highlighted substantial differences between countries in terms of regulatory frameworks, waste management systems, and policy support mechanisms. Lessons from successful international experiences indicate that supportive institutional environments are essential for facilitating sustainable transitions within the construction sector [20-22].

Economic incentives have emerged as particularly important instruments for encouraging circular behavior among construction stakeholders. Government subsidies, green financing mechanisms, tax incentives, and landfill taxes have demonstrated significant potential for influencing organizational decision-making and accelerating the adoption of sustainable technologies. Studies examining environmental taxation and subsidy programs have found that carefully designed financial policies can improve the economic attractiveness of circular construction practices while supporting broader sustainability objectives. Such instruments help internalize environmental costs and encourage investment in resource-efficient technologies and business models [23-26].

Environmental performance remains the ultimate justification for transitioning toward circular construction systems. Comparative evaluations have demonstrated that buildings designed according to circular principles generally exhibit superior environmental performance relative to traditional construction models. Benefits include reduced carbon emissions, lower resource consumption, decreased waste generation, improved water management, and enhanced ecological sustainability. Design strategies emphasizing durability, adaptability, and material recovery contribute significantly to reducing the environmental footprint of construction activities while extending the useful life of building assets [27-29].

The measurement and evaluation of sustainability performance have therefore become increasingly important areas of research and practice. Sustainability indicators and assessment frameworks provide essential tools for monitoring environmental outcomes and supporting evidence-based decision-making. Frameworks developed within European contexts have demonstrated the value of comprehensive performance measurement systems that incorporate environmental, economic, and social dimensions of sustainability. Such frameworks facilitate the evaluation of circular economy interventions and support continuous improvement in construction practices [30, 31].

Furthermore, the successful implementation of circular economy principles depends not only on technological and institutional factors but also on human and organizational capacities. Educational systems, professional training programs, and capacity-building initiatives play essential roles in developing the knowledge and competencies required for sustainable construction practices. The readiness of educational institutions to integrate circular economy concepts into engineering and construction curricula is therefore critical for supporting long-term industry transformation. Similarly, organizational capabilities and institutional capacities significantly influence the effectiveness of integrated circular management models and sustainability initiatives [32, 33].

Recent developments in lifecycle management and industrial symbiosis further highlight the potential for systemic approaches to resource optimization. Lifecycle-oriented strategies emphasize the management of material flows throughout the entire lifespan of built assets, while industrial symbiosis promotes resource exchange among interconnected systems to maximize efficiency and minimize waste. These approaches align closely with the core principles of the circular economy and provide valuable frameworks for enhancing sustainability within complex industrial ecosystems, including the construction sector [34, 35].

Although substantial progress has been made in advancing circular economy research within the construction industry, significant knowledge gaps remain regarding the integration of strategic, technological, institutional, economic, and environmental dimensions into comprehensive frameworks capable of guiding industry-wide transformation. Much of the existing literature focuses on specific technologies, individual policies, or isolated implementation challenges, while fewer studies provide holistic analyses that synthesize these diverse dimensions into coherent strategic models. Consequently, there remains a need for comprehensive investigations capable of identifying, categorizing, and analyzing circular economy strategies while simultaneously examining their implementation barriers, institutional drivers, environmental impacts, and long-term sustainability implications.

Therefore, the aim of this study is to systematically identify and analyze circular economy strategies in the construction industry and develop an integrated strategic framework for enhancing environmental sustainability, improving resource efficiency, and reducing waste generation through the transition from linear to circular construction systems.

2. Methodology

This study was conducted using a qualitative systematic review design. The research aimed to synthesize existing scientific knowledge regarding circular economy strategies in the construction industry and to develop an integrated strategic framework for enhancing environmental sustainability and reducing resource consumption and waste generation. The systematic review approach was selected because the research sought to move beyond project-level technical solutions and identify broader strategic, institutional, and policy-oriented dimensions of circular economy implementation within the construction sector. The review focused on the comprehensive examination of scholarly literature and international reports addressing circular construction, sustainability strategies, resource regeneration, waste management, circular business models, environmental policy, and sustainable value-chain management.

The study sample consisted of published scientific articles, review papers, policy reports, industry documents, and international organizational publications relevant to circular economy implementation in the construction industry. Sources were identified through extensive searches of reputable scientific databases and international repositories specializing in sustainability, environmental management, construction engineering, circular economy, and urban development. Inclusion criteria required documents to address at least one of the following themes: circular economy principles in construction, resource efficiency, construction and demolition waste management, circular business models, sustainable construction policies, environmental sustainability indicators, circular supply chains, or strategic frameworks for circular construction. Documents that lacked direct relevance to the construction industry or failed to provide strategic, managerial, environmental, or policy-related insights were excluded from the review process. The final corpus of literature represented a comprehensive body of evidence encompassing theoretical, empirical, managerial, legal, and policy-oriented perspectives on circular economy implementation within the built environment.

The primary data collection tool was a structured systematic literature review protocol developed to ensure the comprehensive identification, screening, and selection of relevant publications. This protocol guided the search process across scientific databases and institutional repositories using predefined keywords related to circular economy, sustainable construction, construction waste management, resource regeneration, circular business models, environmental sustainability, green buildings, construction supply chains, and circular policies. The protocol facilitated the systematic retrieval of peer-reviewed journal articles, conference papers, technical reports, governmental publications, and documents issued by international organizations. Through this process, the researchers established a comprehensive evidence base representing contemporary developments, theoretical foundations, practical experiences, and policy initiatives associated with circular construction.

A document analysis framework was also employed as a secondary data collection instrument. This framework enabled the systematic extraction of relevant information from selected sources, including definitions, conceptual models, strategic approaches, implementation barriers, institutional drivers, environmental impacts, policy mechanisms, economic incentives, and sustainability outcomes. The framework ensured consistency in data extraction and facilitated the organization of findings into meaningful analytical categories. Particular attention was given to identifying macro-level strategies, strategic pathways, governance mechanisms, resource regeneration practices, life-cycle management approaches, and integrated sustainability frameworks discussed within the literature.

Data analysis was conducted using qualitative content analysis. Following the selection of eligible documents, the researchers performed a comprehensive reading and interpretation of the collected literature to identify recurring concepts, themes, and strategic patterns. The analysis began with open coding, during which key statements, concepts, and strategic elements related to circular economy implementation were extracted from the literature. These codes were then compared, refined, and grouped into broader thematic categories representing major dimensions of circular construction.

Subsequently, an axial coding process was employed to establish relationships among identified categories and to examine interactions between strategies, implementation barriers, institutional drivers, environmental sustainability indicators, and policy mechanisms. Through iterative analysis, themes were integrated into higher-order conceptual domains, including resource regeneration strategies, circular business models, policy and governance frameworks, economic incentives, digital technologies, institutional capacities, and sustainability outcomes. Finally, selective coding was used to synthesize the findings and construct an integrated strategic conceptual framework illustrating the pathways through which circular economy strategies contribute to environmental sustainability and reduced resource consumption within the construction industry. This analytical process enabled the development of a comprehensive understanding of the interrelationships among strategic, managerial, technological, economic, and environmental dimensions of circular construction and supported the formulation of an integrated model for facilitating sustainable transformation in the construction sector.

3. Findings and Results

Following the systematic search, screening, eligibility assessment, and full-text evaluation of the retrieved literature, a final corpus of studies and policy documents related to circular economy implementation in the construction industry was selected for qualitative analysis. The reviewed sources included peer-reviewed journal articles, international reports, policy documents, conceptual papers, and empirical studies addressing circular construction, sustainable resource management, construction and demolition waste management, circular business models, environmental sustainability, and strategic planning. The selected studies represented a diverse range of geographical contexts and methodological approaches, allowing for a comprehensive examination of circular economy strategies across different institutional and industrial settings. The reviewed literature covered topics ranging from circular design principles and sustainable supply chains to policy frameworks, digital technologies, economic incentives, environmental assessment, and governance mechanisms. The breadth of the literature enabled the identification of recurring themes and the development of an integrated conceptual understanding of the strategic transition toward circular construction.

Table 1. Characteristics of the Reviewed Literature

Characteristic	Description
Literature Type	Journal articles, policy reports, industry reports, conceptual papers, review studies
Main Subject Areas	Circular economy, sustainable construction, waste management, resource efficiency, green buildings
Geographical Coverage	Europe, North America, Asia, Middle East, and international comparative studies
Research Approaches	Qualitative, quantitative, mixed-methods, conceptual, and systematic reviews
Primary Focus	Circular strategies, policy frameworks, environmental impacts, business models, technological innovations
Key Stakeholders Examined	Governments, construction firms, architects, engineers, suppliers, developers, end-users
Strategic Levels Identified	Policy level, strategic level, operational level
Sustainability Dimensions	Environmental, economic, social, technological, and institutional sustainability

The analysis of the reviewed literature demonstrates that research on circular economy implementation in the construction sector has evolved considerably over the past decade. Early studies primarily focused on technical solutions such as recycling technologies and construction waste management. More recent investigations have increasingly emphasized strategic governance, institutional frameworks, digitalization, circular business models, and integrated sustainability planning. The reviewed studies consistently highlighted the importance of moving beyond isolated technical interventions toward systemic transformation involving multiple stakeholders and coordinated policy actions. Furthermore, environmental sustainability emerged as the dominant concern across the literature, although economic viability, social acceptance, and technological readiness were also frequently discussed as essential conditions for successful implementation.

Table 2. Classification of Circular Economy Strategies Identified in the Literature

Strategic Category	Main Objective	Expected Outcome
Waste Prevention	Minimize waste generation at source	Reduced resource consumption
Design for Durability	Extend building lifespan	Lower replacement rates
Design for Disassembly	Facilitate future material recovery	Improved reuse opportunities
Material Reuse	Reuse building components directly	Preservation of embodied energy
Advanced Recycling	Convert waste into secondary resources	Reduced landfill dependency
Circular Supply Chains	Establish closed-loop material flows	Resource efficiency
Service-Based Business Models	Shift from ownership to service provision	Increased product responsibility
Material Passports	Enable material tracking	Enhanced transparency
Digital Building Management	Improve lifecycle monitoring	Better decision-making
Resource Regeneration Strategies	Restore material value	Long-term sustainability

The content analysis identified ten major strategic categories that collectively define the transition toward circular construction. Among these, waste prevention emerged as the highest-priority strategy, reflecting the principle that avoiding waste generation is more sustainable than managing waste after it is produced. Design-oriented strategies, particularly design for durability and design for disassembly, were repeatedly identified as foundational mechanisms enabling future resource recovery and reducing lifecycle environmental impacts. Material reuse and advanced recycling were frequently discussed as complementary approaches, with reuse generally providing greater environmental benefits due to the preservation of embodied energy and material value. The findings further revealed growing attention to circular supply chains, service-oriented business models, and digital technologies such as material passports, which facilitate transparency, accountability, and resource traceability across the building lifecycle. Collectively, these strategies illustrate a progressive shift from reactive waste management toward proactive resource stewardship and systemic sustainability.

Table 3. Structural Barriers and Institutional Drivers Affecting Circular Economy Implementation

Structural Barriers	Institutional Drivers
Information asymmetry	Government support programs
Lack of material tracking systems	Public environmental awareness
Regulatory complexity	Sustainability policies
Limited secondary material markets	Financial incentives
Absence of standardized certification	Technological innovation
Organizational resistance to change	Academic and professional training
High initial investment costs	Digital transformation
Fragmented stakeholder coordination	Industry collaboration networks
Uncertainty regarding material quality	International sustainability commitments
Limited technical expertise	Research and development support

The findings indicate that successful implementation of circular economy principles depends not only on technical capabilities but also on overcoming significant institutional and structural barriers. Information asymmetry emerged as one of the most frequently reported obstacles, particularly concerning the availability, quality, and traceability of secondary materials. Regulatory complexity and fragmented governance structures were also identified as major impediments that increase implementation costs and discourage innovation. Simultaneously, several institutional drivers were found to facilitate adoption. Government policies, financial incentives, public awareness campaigns, technological advancements, and educational initiatives were repeatedly highlighted as catalysts for change. The analysis suggests that overcoming barriers requires coordinated interventions across regulatory, technological, organizational, and cultural dimensions rather than isolated solutions targeting a single aspect of the construction ecosystem.

Table 4. Strategic Impacts of Circular Economy Actions on Sustainability Indicators

Sustainability Indicator	Strategic Impact
Carbon Footprint Reduction	High
Resource Conservation	High
Waste Reduction	High
Energy Efficiency	Moderate to High
Water Conservation	Moderate
Biodiversity Protection	Moderate
Landfill Diversion	High
Material Productivity	High
Urban Environmental Quality	Moderate to High
Long-Term Economic Resilience	High

The evaluation of sustainability outcomes revealed that circular economy strategies exert substantial positive effects across multiple environmental and economic indicators. Carbon footprint reduction, resource conservation, waste minimization, and landfill diversion emerged as the most consistently reported benefits. The literature demonstrated that replacing virgin materials with reused or recycled alternatives can significantly reduce greenhouse gas emissions while preserving natural resources and decreasing environmental degradation associated with extraction activities. Additionally, circular construction approaches were associated with improvements in material productivity, energy efficiency, and urban environmental quality. Long-term economic resilience also emerged as a major outcome, as circular business models reduce dependence on volatile raw material markets and create new opportunities within recycling, refurbishment, and remanufacturing sectors. Overall, the findings indicate that circular economy implementation contributes simultaneously to environmental protection, economic sustainability, and industrial competitiveness.

The synthesis of these findings ultimately led to the development of an integrated conceptual framework in which resource regeneration strategies, institutional drivers, digital technologies, and sustainability objectives interact dynamically to support the transition from a linear construction model to a circular and sustainable construction industry. This framework highlights that successful transformation requires coordinated action across policy, strategic, and operational levels, ensuring that environmental, economic, technological, and social dimensions are addressed in a holistic and mutually reinforcing manner.

4. Discussion and Conclusion

The findings of this systematic review provide strong evidence that the circular economy has evolved from a theoretical sustainability concept into a comprehensive strategic framework capable of transforming the construction industry. The review identified a set of interrelated macro-strategies that collectively support the transition from a linear model of resource consumption toward a regenerative system based on resource efficiency, waste prevention, material recovery, and lifecycle value preservation. The results demonstrated that circular economy implementation in the construction industry is most effective when it is approached as an integrated system encompassing design, procurement, construction, operation, maintenance, and end-of-life management rather than as a collection of isolated technical interventions. This finding supports earlier arguments that sustainability in infrastructure and construction projects requires strategic integration across organizational and project boundaries rather than reliance on individual waste management practices [3, 6]. The reviewed literature consistently indicated that successful circular construction depends on long-term strategic planning, coordinated governance mechanisms, and collaboration among multiple stakeholders throughout the construction value chain.

One of the most significant findings of this study was the identification of waste prevention, design for durability, design for disassembly, material reuse, advanced recycling, circular supply chains, digital resource tracking, and service-oriented business models as the primary strategic pillars of circular construction. Among these strategies, waste prevention emerged as the most influential because it addresses environmental challenges at their source rather than attempting to manage waste after it has been generated. This finding aligns with studies emphasizing the importance of resource efficiency and lifecycle thinking in sustainable architecture and urban planning [1]. Similarly, the prominence of design-oriented strategies confirms the argument that decisions made during early project phases have a disproportionate influence on long-term environmental performance. Previous research has shown that durable and adaptable building designs reduce replacement frequency, preserve embodied resources, and lower lifecycle carbon emissions, thereby supporting sustainability objectives across multiple dimensions [5, 28]. The present findings therefore reinforce the growing consensus that design decisions are among the most powerful leverage points for achieving circularity in the built environment.

The results further revealed that material reuse and advanced recycling represent complementary but distinct pathways toward circular construction. Reuse strategies were found to preserve material value more effectively because they maintain the physical and functional integrity of building components, whereas recycling often involves some degree of material transformation and energy consumption. This finding is consistent with research emphasizing the strategic importance of secondary material markets and material exchange platforms in facilitating resource circulation within the construction industry [19]. Furthermore, studies examining technological innovations in recycling systems have highlighted the need for advanced processing techniques capable of maintaining material quality and increasing stakeholder confidence in recycled products [13]. The integration of reuse and recycling strategies therefore appears essential for maximizing environmental benefits while minimizing dependence on virgin resource extraction.

Another important finding concerns the increasing significance of digitalization as a facilitator of circular economy implementation. The review demonstrated that digital technologies such as Building Information Modeling (BIM), material passports, integrated databases, and digital tracking systems play a central role in enabling transparency, traceability, and informed decision-making throughout the construction lifecycle. Information generated through these technologies allows stakeholders to monitor material flows, identify reuse opportunities, and optimize resource management practices. These findings strongly support previous studies emphasizing the transformative potential of digitalization in developing circular value chains and improving waste management performance [15, 16]. Likewise, investigations into material passports have shown that digital documentation systems facilitate end-of-life recovery and improve the economic viability of secondary material markets [17]. The current findings suggest that digital infrastructure is no longer a supplementary component of circular construction but rather a foundational requirement for achieving systemic transformation.

The analysis of implementation barriers revealed that information asymmetry, regulatory complexity, fragmented governance structures, limited market maturity, and insufficient stakeholder coordination remain major obstacles to circular economy adoption. Among these barriers, information asymmetry emerged as particularly influential because uncertainty regarding material quality, availability, and performance undermines confidence in secondary materials and discourages investment in circular solutions. This finding closely corresponds with previous studies identifying information gaps as a major impediment to the development of circular material markets [18]. Additionally, administrative bureaucracy and regulatory fragmentation were found to create substantial transaction costs that hinder innovation and reduce organizational willingness to adopt circular practices. Similar conclusions have been reported by studies examining institutional barriers within the Iranian construction industry, which emphasize the need for regulatory reforms and streamlined governance mechanisms to facilitate sustainability transitions [7, 22].

The findings also highlighted the critical role of institutional drivers in overcoming implementation challenges. Government policies, public awareness, educational initiatives, research and development investments, and industry collaboration networks were identified as key enabling factors supporting circular economy adoption. The importance of policy support is consistent with research emphasizing the role of macro-level governance frameworks in creating favorable conditions for sustainable development within the construction sector [36]. Similarly, studies examining successful international experiences have demonstrated that policy coherence, stakeholder engagement, and institutional coordination are essential prerequisites for large-scale circular economy implementation [20, 21]. The present findings therefore suggest that technical innovation alone is insufficient and must be accompanied by supportive institutional environments capable of encouraging behavioral and organizational change.

Economic incentives emerged as another major theme throughout the reviewed literature. The findings demonstrated that subsidies, tax incentives, landfill taxes, green financing mechanisms, and other financial instruments significantly influence organizational decision-making and investment behavior. Financial incentives were found to be particularly effective when aligned with environmental objectives and supported by transparent regulatory frameworks. This result is consistent with previous studies showing that economic instruments can encourage resource-efficient behavior, increase investment in sustainable technologies, and accelerate the adoption of circular business models [23, 24]. Furthermore, government subsidy programs have been shown to reduce financial risks associated with emerging green technologies and improve their competitiveness relative to conventional alternatives [25, 26]. These findings underscore the importance of integrating economic and environmental considerations within policy frameworks designed to promote sustainable construction.

The review also emphasized the growing importance of circular business models in transforming traditional construction practices. Service-oriented models, product-service systems, leasing arrangements, and value-retention strategies were found to offer significant opportunities for enhancing resource productivity and reducing waste generation. These approaches shift the focus from ownership toward performance and lifecycle value creation, thereby encouraging manufacturers and service providers to prioritize durability, reparability, and resource recovery. This finding supports earlier research highlighting the strategic potential of service-based business models for advancing circular economy objectives within the construction industry [10, 11]. However, the results also confirmed that legal uncertainty, financial risks, and institutional inertia continue to limit the widespread adoption of such models, particularly in developing contexts [12].

Environmental sustainability outcomes represented one of the strongest areas of consensus across the reviewed literature. The findings demonstrated that circular economy strategies contribute substantially to reductions in carbon emissions, resource consumption, waste generation, landfill dependency, and environmental degradation. Carbon footprint reduction emerged as one of the most frequently reported benefits, reflecting the ability of circular practices to preserve embodied energy and reduce demand for energy-intensive raw material production. This finding aligns with studies estimating substantial carbon reductions through the use of secondary materials and circular design principles [31]. Likewise, comparative evaluations of circular and traditional building systems have consistently demonstrated superior environmental performance among projects incorporating circular economy principles [27]. Additional benefits identified in the literature include improved water resource management, reduced ecological pressure on natural systems, and enhanced urban environmental quality [5, 29].

A particularly important contribution of the findings is the recognition that circular economy implementation requires a holistic and integrated management framework. The reviewed studies consistently emphasized the interdependence of technical, economic, institutional, digital, and social dimensions. Sustainable outcomes were most likely to occur when these dimensions were aligned within coherent strategic frameworks rather than addressed independently. This conclusion is strongly supported by studies proposing integrated approaches to project management, resource governance, and value chain coordination [9, 37]. The concept of systemic synergy identified throughout the literature suggests that successful circular construction depends on coordinated interactions among diverse stakeholders and institutions operating across multiple scales.

The findings further underscore the importance of human and organizational capacities in supporting long-term sustainability transitions. Educational systems, professional development programs, and organizational learning processes were repeatedly identified as essential mechanisms for developing the competencies required to implement circular economy principles effectively. This observation aligns with previous research examining educational readiness and institutional capacity development within the construction sector [32, 33]. Without adequate knowledge, skills, and organizational support, even the most advanced technologies and policy frameworks may fail to achieve their intended outcomes.

Finally, the results support emerging perspectives that view circular construction as part of a broader transition toward industrial symbiosis and lifecycle-based resource management. By integrating material flows, technological systems, and organizational processes across the entire built environment, circular economy strategies create opportunities for enhancing resilience, sustainability, and long-term economic performance. This finding is consistent with lifecycle management approaches emphasizing resource circulation, industrial ecosystem optimization, and systemic sustainability outcomes [34, 35]. Collectively, the evidence reviewed in this study demonstrates that circular economy principles provide a viable and increasingly necessary framework for addressing the environmental and resource challenges facing the contemporary construction industry.

The present study has several limitations. As a systematic review based on existing literature, its findings depend on the quality, scope, and methodological rigor of previously published studies. The review synthesized evidence from diverse contexts, methodologies, and geographical regions, which may limit the direct comparability of findings across studies. Furthermore, because the available literature is continuously expanding, newly published research may introduce additional insights that were not included in the present analysis. The study also focused primarily on strategic and conceptual dimensions of circular construction rather than conducting empirical validation of the proposed framework within specific construction projects or organizations.

Future research should focus on empirical testing of integrated circular economy frameworks within real-world construction environments. Longitudinal studies examining the implementation and performance of circular strategies across the entire building lifecycle would provide valuable evidence regarding their effectiveness and practical challenges. Additional investigations are needed to evaluate the economic feasibility of service-based business models, assess the long-term impacts of digital material tracking systems, and explore stakeholder behavior within emerging circular construction ecosystems. Comparative studies across different countries and regulatory environments could also enhance understanding of contextual factors influencing successful implementation.

From a practical perspective, industry stakeholders should prioritize the development of integrated strategies that combine technological innovation, policy support, stakeholder collaboration, and organizational learning. Construction firms should invest in digital resource management systems, establish partnerships for material recovery and reuse, and incorporate circular principles into procurement and project planning processes. Policymakers should create supportive regulatory frameworks, expand financial incentives for sustainable construction practices, and promote industry-wide standards for material tracking and lifecycle management. Educational institutions and professional organizations should strengthen training programs related to circular economy concepts, ensuring that future construction professionals possess the knowledge and competencies required to support the transition toward a more sustainable and resource-efficient built environment.

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Authors equally contributed to this article.

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Declaration of Interest

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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