

Review Article

Circular Economy Strategies for Construction and Demolition Waste Management: A Systematic Review of Barriers, Technologies, and Implementation Pathways

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Abstract

Construction and demolition waste (CDW) is one of the most resource-intensive waste streams generated by the built environment, and its management has become central to circular economy transitions. This systematic literature review examines how circular economy strategies are being conceptualized and implemented in CDW management, with specific attention to barriers, enabling technologies, implementation pathways, and future research needs. The review was based on a Scopus-derived dataset and followed a structured procedure involving keyword-based searching, eligibility screening, thematic extraction, and integrative synthesis. Evidence was organized into four themes: circular economy strategies, barriers and challenges, technologies and digital tools, and implementation pathways. The review shows that circular CDW management is increasingly moving beyond conventional end-of-pipe recycling toward lifecycle-oriented strategies, including waste prevention, design for disassembly, selective demolition, component reuse, recycled-content procurement, and high-quality material recovery. However, adoption remains constrained by technical barriers, weak secondary-material markets, fragmented regulation, limited stakeholder coordination, low awareness, and insufficient data transparency. Digital technologies such as building information modelling, life-cycle assessment, artificial intelligence, deep learning, blockchain, digital waste recognition, and material passports offer promising support for waste prediction, material traceability, sorting, and circular decision-making. Nevertheless, these technologies require reliable data, interoperability, institutional readiness, and validation in real construction and demolition projects. It concludes that the transition to circular CDW management depends on aligning upstream design decisions, policy instruments, business models, stakeholder collaboration, and technology-enabled material-flow governance.

Keywords: Construction and demolition waste; Circular economy; Circular construction; Waste management; Digital technologies.

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Introduction

Construction and demolition waste (CDW) has become one of the most visible material consequences of urbanization, infrastructure renewal, and building-sector expansion. Unlike many waste streams, CDW is closely tied to long-lived material stocks, capital-intensive projects, and complex supply chains involving designers, contractors, demolition firms, waste processors, regulators, and material suppliers. The scale of CDW generation has made it a strategic concern for both environmental management and construction-sector transformation. Studies on Europe, China, and other rapidly developing construction markets show that CDW is not merely a disposal problem but a resource-management challenge involving recoverable aggregates, concrete, masonry, timber, metals, plasterboard, and building components [1-4]. In this context, circular economy thinking offers a shift from waste treatment at end of life toward lifecycle resource stewardship. Circular economy principles are particularly relevant to CDW because buildings and infrastructure store large quantities of materials for long periods before those materials re-enter the economy as demolition, renovation, or replacement flows. The circular objective is therefore not only to recycle waste after demolition but also to reduce waste generation, extend building and component lifetimes, enable adaptive reuse, improve selective demolition, and recover materials at sufficient quality for reintegration into construction markets. This is consistent with studies that emphasize cleaner production, 3R practices, adaptive reuse, secondary material substitution, and material-efficiency strategies as core routes for reducing the environmental burden of construction [5-9]. The built environment therefore requires circularity to be considered across design, procurement, construction, use, renovation, demolition, and post-demolition processing.

Despite this conceptual promise, the transition from linear CDW disposal to circular construction remains uneven. In many contexts, waste-management systems still rely heavily on collection, mixed-waste treatment, downcycling, and landfill diversion rather than higher-value circular practices. China's CDW recycling system, for example, has been described as facing operational, regulatory, and market challenges even where policy attention is growing [10]. Similarly, research on the European Union reveals substantial variation in CDW generation and recovery practices across countries, reflecting differences in policy maturity, market development, infrastructure, and stakeholder behaviour [4]. These findings suggest that circular CDW management cannot be reduced to a single recycling technology or policy instrument; rather, it requires coordination among material quality, design choices, market incentives, regulations, business models, and stakeholder practices. Current literature on circular CDW management is expanding rapidly but remains fragmented across several research communities. Some studies focus on technical strategies such as recycled aggregates, recycled cementitious materials, prefabrication, selective demolition, design for disassembly, and adaptive reuse [3,11-13]. Others examine barriers and enablers related to regulation, stakeholder awareness, institutional pressure, supply-chain collaboration, and circular business models [14-19]. A third body of work investigates digital and technological enablers, including building information modelling (BIM), life-cycle assessment (LCA), artificial intelligence, deep learning, material-flow analysis, and blockchain-based traceability [20-24].

This fragmentation creates a gap in synthesis. Existing reviews have addressed circular construction, CDW recycling, building-sector circularity, and waste-management research more broadly, but an integrated review is still needed to connect four analytical dimensions: strategies, barriers, technologies, and implementation pathways. This integration is important because circular strategies are rarely implemented successfully without addressing barriers, technologies are not transformative without governance and market support, and implementation pathways remain weak if they do not connect design, policy, business models, and stakeholder

coordination. The literature on public procurement, carbon-saving materials, circular business models, and sustainable construction further demonstrates that CDW circularity is embedded in wider sustainability transitions rather than operating as a narrow waste-management issue [25-28]. The objective of this systematic literature review is to synthesize circular economy strategies for construction and demolition waste management, with specific attention to barriers, technologies, and implementation pathways. The review is guided by five research questions: (1) What circular economy strategies have been proposed or implemented for CDW management? (2) What barriers limit the adoption of circular CDW management across policy, market, organizational, behavioural, and technical contexts? (3) What technologies support CDW material recovery, traceability, prediction, and decision-making? (4) What implementation pathways can support the transition from linear CDW disposal to circular construction systems? and (5) What future research directions are needed to advance circular CDW management? The scientific contribution of this review is an integrated evidence-based framework linking circular strategies, barriers, technological enablers, and implementation pathways for CDW management.

Methods and Theoretical Background

Method

This systematic literature review adopted a structured search and synthesis strategy to identify research on circular economy strategies for CDW management (**Figure 1**). The primary evidence source was Scopus, selected because of its broad indexing of peer-reviewed literature in environmental science, engineering, construction management, waste management, materials science, and sustainability. The search strategy was organized around three concept blocks: (1) construction and demolition waste, (2) circular economy and circularity, and (3) management, implementation, barrier, and technology dimensions. The working search logic combined terms such as “construction and demolition waste,” “C&D waste,” “construction waste,” and “demolition waste” with “circular economy,” “circularity,” and “resource circularity,” and with strategy-oriented terms including “recycling,” “reuse,” “recovery,” “barrier,” “technology,” “implementation,” “policy,” “governance,” “framework,” and “model.” The search was conducted in title, abstract, and keyword fields. The final exported dataset contained 100 Scopus records published between 2017 and 2025, all classified as articles. This time span captures recent growth in circular economy research and digital construction technologies while retaining foundational studies in circular CDW management.

Eligibility Criteria

Eligibility criteria were established to ensure conceptual consistency and relevance to the review objective. Included studies had to address CDW, construction waste, demolition waste, built-environment material flows, circular construction, recycled building materials, or directly related resource recovery systems. Studies were included when they addressed at least one of the following themes: circular economy strategies, waste reduction, reuse, recycling, recovery, material circularity, barriers, enabling policies, stakeholder behaviour, technology, digital tools, or implementation pathways. Peer-reviewed journal articles were prioritized, and English-language publications were retained because the exported Scopus dataset was composed of English article records. Studies were excluded when they focused only on general circular economy without a construction or built-environment waste component; when they addressed unrelated waste streams without relevance to construction materials; or when they lacked sufficient metadata, abstract content, or substantive connection to strategies, barriers, technologies, or implementation. Conceptual clarity was important because circular economy

terms can be used inconsistently across recycling, reuse, refurbishment, remanufacturing, and broader value-retention practices [29].

Screening, Selection, and Risk-of-Bias Analysis

The screening procedure followed a staged approach. First, 100 records were identified from the Scopus export. No duplicate DOI or title records were found in the dataset. Second, titles and abstracts were screened for relevance to CDW, circular construction, building-sector material flows, waste recycling, reuse, recovery, digital technologies, policy mechanisms, and implementation barriers. Records that were too broad, marginally related to CDW, or focused on unrelated waste systems were not prioritized for the thematic tables, although some broader circular economy and digital transformation studies were retained as supporting references where they directly informed theoretical framing or discussion. Third, studies were categorized according to four synthesis themes: circular strategies, barriers and challenges, technologies and digital tools, and implementation pathways. Risk-of-bias was assessed qualitatively by examining topic relevance, methodological transparency, clarity of circular economy framing, appropriateness of evidence, and contribution to the review questions. Because the evidence base included empirical, review, modelling, behavioural, technology, and policy studies, a single clinical-style risk-of-bias tool was not appropriate. Instead, the review used relevance and credibility criteria suited to a heterogeneous SLR.

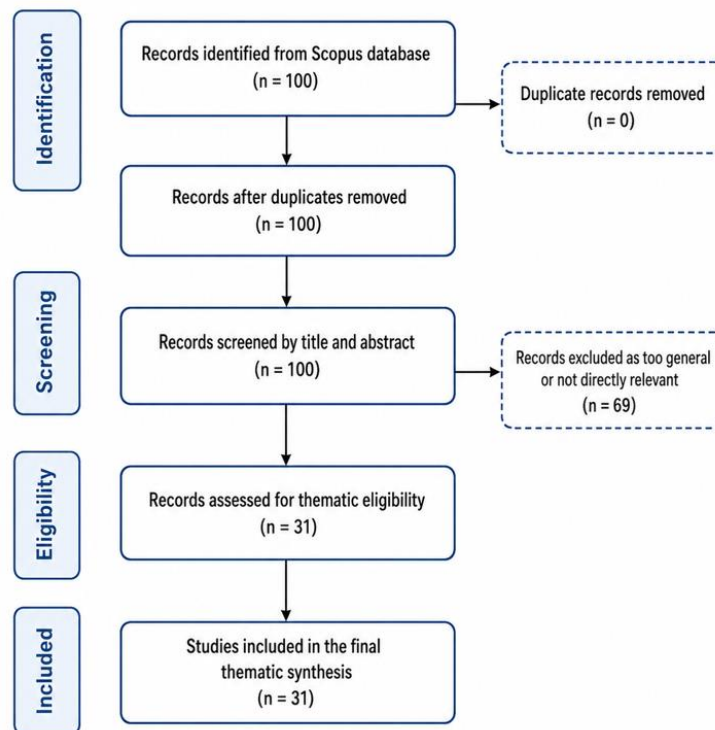


Figure 1. PRISMA Flow Diagram

Data Extraction and Synthesis Approach

Data extraction was thematic and integrative. For each selected study, information was extracted on author and year, geographical or sectoral context, CDW stream or material focus, circular strategy, barrier category, technology or tool, lifecycle stage, implementation mechanism, key finding, and circular economy contribution. Evidence from 31 unique references was synthesized

in **Tables 1–4**, while 60 references were used to support the manuscript’s introduction, methods, theoretical background, and discussion. The synthesis approach was informed by methods used in bibliometric, text-mining, content-analysis, life-cycle assessment, life-cycle costing, system dynamics, and digital sustainability research [30]-[33]. The purpose was not only to summarize studies but also to identify cross-cutting patterns, contradictions, gaps, and future research needs. This approach allows the review to connect circular economy theory with practical CDW management strategies and implementation challenges.

Identification: 100 records were exported from Scopus. Screening: 100 records were screened by title, abstract, and metadata after duplicate checking. Eligibility: records were assessed for relevance to CDW, circular economy, strategies, barriers, technologies, and implementation pathways. Inclusion: 31 unique references were included in **Tables 1–4** for detailed thematic synthesis, and 60 references were retained as supporting literature across the full manuscript.

Theoretical Background

Circular Economy and Resource-Loop Thinking in Construction

Circular economy theory provides the central lens for interpreting CDW management as a resource-loop problem rather than a disposal problem (**Figure 2**). The traditional construction model is linear: raw materials are extracted, processed into products, assembled into buildings, and eventually discarded after renovation or demolition. Circular economy reorients this model toward narrowing, slowing, closing, and regenerating material flows [34]. In construction, this means reducing virgin material input, extending the useful life of buildings and components, recovering materials at high quality, and designing systems in which demolition outputs become inputs for future projects. These objectives are consistent with the waste hierarchy but go beyond it by emphasizing value retention rather than only landfill diversion. Circular CDW management therefore requires attention to material loops, reuse cascades, secondary raw materials, product-service systems, and lifecycle information flows [29-35]. Resource-loop thinking also implies that circularity must begin before waste is generated. Design for disassembly, modular construction, prefabrication, adaptive reuse, and material passports are upstream interventions that can improve downstream recovery. Prefabricated and modular systems can reduce waste during construction and make component reuse easier at the end of life [11,12]. Similarly, circular building design strategies can slow, narrow, and close loops through adaptability, repairability, material efficiency, and end-of-life planning [13]. From this perspective, CDW management is not only the responsibility of waste processors but also of designers, clients, procurement officers, suppliers, contractors, and demolition specialists.

Evolution of Construction and Demolition Waste Management Practices

CDW management has evolved from conventional disposal and landfill diversion toward more complex circular construction practices. Early approaches emphasized collection, transport, site sorting, and recycling, often with the goal of meeting waste-recovery targets. More recent literature has expanded the focus to include selective demolition, recycled aggregate quality, recycled cementitious materials, green procurement, adaptive reuse, industrial symbiosis, and digital information systems. The evolution reflects a growing recognition that recycling alone may lead to downcycling when recovered materials are used in lower-value applications, whereas circular economy requires maintaining or increasing material value where possible [31,36,37]. Building stock and material-flow studies deepen this evolution by showing that demolition waste is the delayed output of accumulated material stocks. Embodied environmental requirements in

urban building stocks, future non-structural replacement flows, and global stock-flow models all indicate that future CDW generation depends on historical construction, building lifetimes, renovation cycles, and urban growth patterns [38-41]. CDW circularity therefore requires predictive planning, spatial analysis, and material-flow accounting, rather than reactive treatment after waste has already been generated. This shift strengthens the case for integrating CDW management with urban planning, building design, digital inventories, and material-market development.

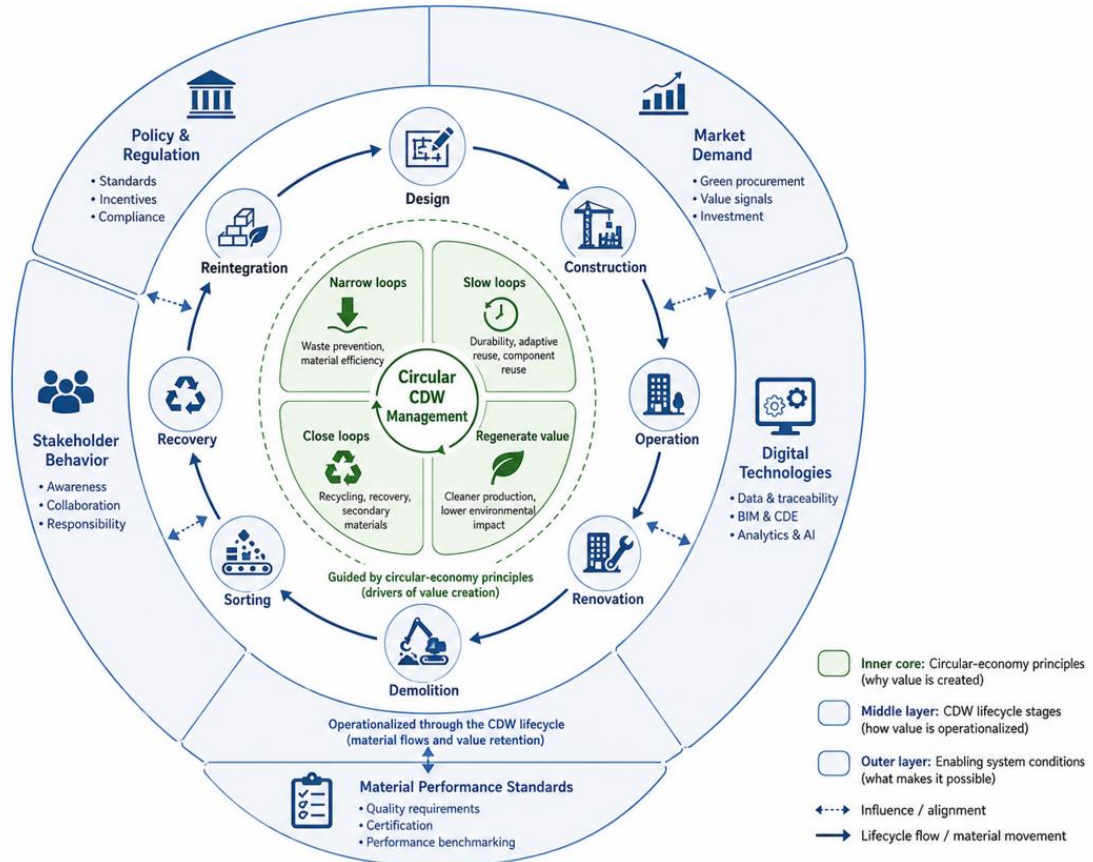


Figure 2. Conceptual foundation of circular construction and demolition waste management.

Barriers, Enablers, and Transition Challenges in Circular CDW Systems

Although circular CDW management is conceptually attractive, implementation remains constrained by interdependent barriers. Technical barriers include contamination, inconsistent material quality, lack of selective demolition, limited sorting infrastructure, weak data on material composition, and uncertain engineering performance of recovered materials. Economic barriers include high processing costs, low virgin material prices, unstable demand for secondary materials, and uncertain returns on circular business models. Regulatory barriers include inconsistent enforcement, fragmented standards, limited incentives, and insufficient procurement requirements. Organizational and behavioural barriers include low stakeholder awareness, risk aversion, supply-chain fragmentation, and lack of coordination across project phases [14-16,42,43].

Digital transformation is increasingly discussed as an enabler of circular CDW systems, but it is not a complete solution. BIM, artificial intelligence, deep learning, blockchain, digital twins,

LCA tools, and material passports can support waste prediction, component inventories, material traceability, environmental assessment, and recovery planning [20-23,44,45]. However, their impact depends on data quality, interoperability, cost, organizational readiness, and policy alignment. The theoretical background therefore suggests an integrated transition perspective: circular CDW management requires the alignment of resource-loop thinking, lifecycle design, digital information systems, economic incentives, and governance mechanisms.

Table 1. Essential summary of circular economy strategies for construction and demolition waste management

References	Circular strategy	CDW stream or material focus	Lifecycle stage	Key findings	Circular economy contribution
Gálvez-Martos et al. [1]	Best management practices across the construction value chain	Construction and demolition waste, plasterboard, recycled aggregates	Design, construction, demolition, treatment	The study synthesizes European best practices for reducing waste generation, minimizing transport impacts, and improving the quality of secondary materials.	Provides an integrated value-chain approach for improving resource efficiency and reducing environmental impacts in CDW systems.
Huang et al. [2]	3R principle: reduce, reuse, recycle	Construction and demolition waste in China	Construction, demolition, recycling	CDW accounts for 30–40% of total waste in China, while the average recycling rate is reported at only about 5%.	Demonstrates the need to operationalize 3R principles to support circular CDW management in rapidly urbanizing contexts.
Ghisellini et al. [5]	Circular economy and cleaner production	Construction and demolition sector	Production, consumption, recovery	The review emphasizes reuse and recycling as strategies for reducing waste generation under a cradle-to-cradle perspective.	Connects CDW management with broader circular economy and cleaner production principles.
Minunno et al. [11]	Circular strategies for prefabricated buildings	Prefabricated building components	Design, manufacturing, construction, demolition	Prefabrication can support reduction, reuse, adaptability, and recyclability of building components.	Shows how industrialized and prefabricated construction can facilitate circular building material flows.
Minunno et al. [12]	Design for disassembly and component reuse	Modular building components	Design, use, end-of-life	The study finds that reuse practices in modular buildings may deliver greater environmental benefits than recycling alone.	Reinforces the importance of prioritizing higher-value circular strategies such as reuse before recycling.
Ghaffar et al. [46]	Integrated C&D waste management for resource recovery	Construction and demolition waste	Demolition, recovery, recycling	The study examines pathways to circular construction through reuse, recycling, and resource recovery practices in the UK.	Provides a transition-oriented strategy for shifting from conventional CDW disposal to circular construction.
Eberhardt et al. [13]	Circular building design strategies	Building materials and components	Design and construction	Circular strategies include slowing, narrowing, and closing material loops through reuse, repair, refurbishment, recycling, and recovery.	Highlights design-stage interventions as central to reducing resource consumption and waste generation.
Di Maria et al. [31]	High-quality recycling instead of downcycling	Construction and demolition waste	End-of-life and recycling	The study combines life-cycle assessment and life-cycle costing to compare end-of-life CDW scenarios.	Supports evidence-based policy for improving recycling quality and avoiding low-value downcycling.
Bao and Lu [47]	Efficient circularity in fast-emerging economies	Construction and demolition waste in Shenzhen	Collection, treatment, recycling, governance	The study reports lessons from Shenzhen on rapidly developing a circular CDW	Offers strategic insights for emerging economies facing rapid urbanization and rising CDW volumes.

				management system from a low base.	
Villoria Sáez and Osmani [4]	CDW generation and recovery assessment	Construction and demolition waste in the EU	Generation, recovery, recycling	The study examines CDW generation and recovery in relation to economic, social, and technological factors across EU countries.	Provides empirical grounding for evaluating CDW recovery performance and circular transition readiness.

Results

Circular Economy Strategies for Construction and Demolition Waste Management

The first synthesis theme concerns the strategies used to translate circular economy principles into CDW management practice. As shown in **Table 1**, the literature emphasizes both upstream and downstream interventions. Upstream strategies include waste prevention, design for disassembly, modular construction, prefabrication, adaptive reuse, and circular building design. These strategies reduce waste before it enters the waste-management system and support higher-value recovery at end of life. Minunno et al. [11] and Minunno et al. [12] show that prefabrication and modularity can support reduction, reuse, adaptability, and recyclability, while Eberhardt et al. [13] emphasize slowing, narrowing, and closing loops through design and construction decisions. Foster [7] extends this logic by showing that adaptive reuse can preserve built assets and reduce environmental impacts associated with demolition and new construction.

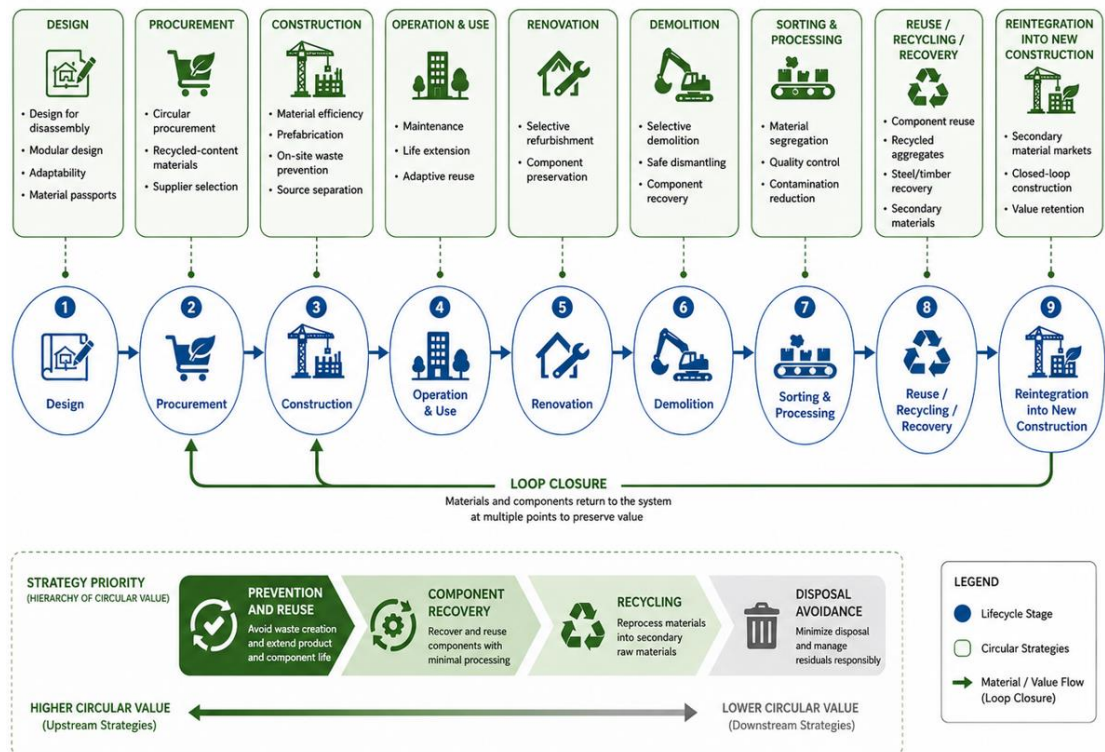


Figure 3. Conceptual foundation of circular construction and demolition waste management.

Downstream strategies remain important but must be designed to avoid low-value outcomes. Recycling and recovery of CDW into secondary materials can reduce virgin material demand, but the environmental and economic value of recycling depends on material quality,

processing methods, and market uptake. Di Maria et al. [31] demonstrate that high-quality recycling should be distinguished from downcycling, while Akhtar and Sarmah [3] and Zhang et al. [37] show that the performance of recycled aggregates is central to their practical use in construction. Gálvez-Martos et al. [1], Huang et al. [2], Ghisellini et al. [5], and Ghaffar et al. [46] further show that effective strategies require integration across the construction value chain, including design, site practice, demolition, treatment, and secondary material use. Thus, circular CDW strategies must be understood as an ordered portfolio: prevention and reuse should be prioritized where feasible, followed by recycling and recovery that preserve material value (Figure 3).

Barriers and Challenges to Circular CDW Management

The second synthesis theme focuses on barriers that prevent circular CDW management from becoming mainstream. Table 2 shows that barriers are multidimensional and mutually reinforcing. Mahpour [15] identifies a wide range of barriers that slow circular economy adoption in CDW management, while Bilal et al. [16] frame the building sector’s circular barriers as structural and systemic. Technical constraints include poor waste separation, contamination, inconsistent quality of recovered materials, insufficient recycling infrastructure, and limited data on material composition. These technical barriers interact with economic barriers, including processing costs, low prices for virgin materials, market uncertainty, and weak demand for secondary materials. As Bao and Lu [47] show, fast-emerging economies face particular challenges when rapid urbanization generates CDW faster than infrastructure, governance capacity, and secondary markets can develop.

Policy, organizational, and behavioral barriers are equally significant. Adams et al. [14] argue that circular economy in construction is often understood narrowly as recycling, reflecting limited awareness and insufficient systems thinking. Guerra and Leite [17] similarly show that United States construction stakeholders recognize circular economy potential but face major challenges and uneven enablers. Giorgi et al. [18] demonstrate that circular economy policies and practices differ across European countries and that policy-practice gaps can limit implementation. Behavioral evidence from Jain et al. [48] indicates that recycling behavior depends on attitudes, institutional pressures, subjective norms, and environmental consciousness. These findings suggest that barriers cannot be solved by technology alone; they require regulatory clarity, stakeholder engagement, market development, circular procurement, training, and institutional incentives.

Table 2. Essential summary of barriers and challenges to circular construction and demolition waste management

References	Barrier category	Specific barrier identified	Context or stakeholder affected	Consequences for circularity	Suggested mitigation or implication
Mahpour [15]	Multidimensional barriers	Twenty-two barriers to adopting circular economy in C&D waste management	CDW management actors	Barriers prevent efficient resource exploitation and slow circular economy adoption.	Prioritization of barriers can help decision-makers target the most critical obstacles first.
Adams et al. [14]	Awareness and systems barriers	Limited awareness, immature circular practices, and lack of systems thinking	Construction industry stakeholders	Circular economy is often reduced to waste minimization and recycling rather than value retention.	New business models and system-level thinking are needed to retain material value.
Jin et al. [49]	Practice and perception barriers	Challenges perceived by practitioners in C&D waste recycling and reuse	Chinese construction practitioners	Practical constraints limit the expansion of recycling and reuse in China.	Practitioner-oriented recommendations are needed to improve recycling acceptance and implementation.

Ma et al. [10]	Policy and operational barriers	Weak practical execution of policies, low recycling effectiveness, and recycling plant challenges	Chinese cities and recycling facilities	Large volumes of C&D waste remain unmanaged despite policy attention.	Policy implementation, plant operation, and market conditions need coordinated improvement.
Giorgi et al. [18]	Policy and stakeholder barriers	Gaps between circular economy policies and actual practices across five European countries	Building-sector stakeholders	Circularity strategies remain unevenly applied due to policy-practice gaps.	Stakeholder engagement and policy alignment are necessary to accelerate adoption.
Guerra and Leite [17]	Awareness, market, and implementation barriers	Limited awareness, major challenges, and uneven enablers among US AEC stakeholders	Architectural, engineering, and construction stakeholders	Low awareness and fragmented practice constrain circular economy implementation.	Awareness-building and enabling factors are required to support transition from linear to circular models.
Jain et al. [48]	Behavioral and institutional barriers	Perceived costs, subjective norms, perceived behavioral control, and institutional pressures	Builders in India	Recycling behavior depends on attitudes, environmental consciousness, and regulatory/normative pressures.	Behavioral intention can be improved by institutional pressure, environmental awareness, and perceived benefits.
Bilal et al. [16]	Structural and mitigation barriers	Current barriers to circular economy in the building sector	Building-sector organizations	The linear economic model continues to dominate resource consumption and waste generation.	A mitigation framework is needed to address interrelated barriers systematically.
Bao and Lu [47]	Capacity and governance barriers	Fast growth without sufficient CDW management capacity	Fast-emerging economies	Rapid construction activity can overwhelm waste management systems.	Circular CDW systems require governance capacity, infrastructure, and market development.
Densley Tingley et al. [50]	Material reuse barriers	Practical barriers to structural steel reuse	UK construction industry	Structural steel reuse remains underexploited despite embodied-carbon benefits.	Barriers must be addressed through design, logistics, market confidence, and stakeholder coordination.

Technologies and Digital Tools Enabling Circular CDW Management

The third synthesis theme addresses technologies and digital tools. **Table 3** shows that enabling technologies can be grouped into assessment tools, predictive tools, classification tools, traceability systems, and lifecycle decision-support systems. BIM-based methods are especially relevant because they connect building information with material quantities, component characteristics, salvage potential, and lifecycle performance. Akanbi et al. [20] use BIM to estimate whole-life salvage performance, while Akanbi et al. [51] develop a disassembly and deconstruction analytics system to support end-of-life planning. Hao et al. [24] connect BIM with life-cycle assessment to evaluate carbon-emission reduction in prefabrication construction. These studies show that digital tools can shift CDW management upstream by enabling design-stage decisions about material recovery and circularity.

Artificial intelligence and deep learning also show potential for improving waste prediction and sorting. Akanbi et al. [21] develop a deep learning model for demolition waste prediction, while Davis et al. [23] classify construction waste materials using deep convolutional neural networks. Majchrowska et al. [52] demonstrates wider applications of deep learning-based waste detection in natural and urban environments. These tools can improve material recognition, classification accuracy, and recovery efficiency, but their performance depends on data quality, image availability, model training, and deployment in real project conditions. LCA, LCC, system dynamics, and digital waste recycling approaches add further analytical capacity by supporting

scenario comparison, environmental assessment, economic evaluation, and dynamic modeling [31], [32], [53]. The evidence indicates that technology can enable circular CDW systems but only when embedded in practical workflows, standards, and governance arrangements (Figure 4).

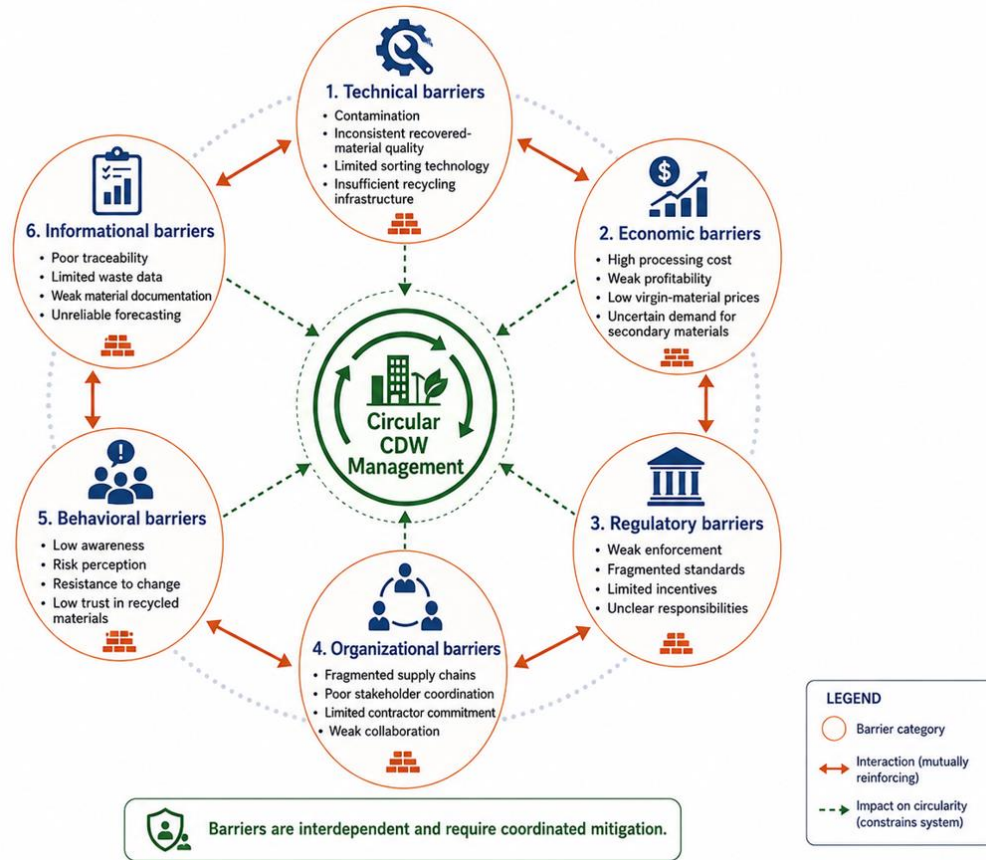


Figure 4. Conceptual foundation of circular construction and demolition waste management.

Table 3. Essential summary of technologies and digital tools enabling circular CDW management

References	Technology or tool	Function in CDW management	Circular economy role	Benefits reported	Limitations or implementation challenges
Hao et al. [24]	BIM-based life-cycle assessment	Assesses carbon emissions during prefabrication materialization	Supports low-carbon and waste-reducing prefabrication strategies	Enables evaluation of prefabrication-related carbon reduction and material impacts.	Requires reliable project data and integration between BIM and environmental assessment workflows.
Akanbi et al. [21]	Deep learning model	Predicts demolition waste and salvageable materials	Supports end-of-life material recovery and reuse planning	Predicts quantities of salvage and waste materials from buildings.	Model effectiveness depends on data quality, building information, and validation in real demolition contexts.
Çetin et al. [22]	Circular digital built-environment framework	Maps digital technologies that enable circularity in the built environment	Connects digitalization with circular design, business models, and material-loop strategies	Clarifies how digital tools can enable circular economy implementation in buildings.	The field remains emerging and requires stronger empirical validation.

Davis et al. [23]	Deep convolutional neural network	Classifies construction waste materials using digital images	Improves sorting, separation, and recovery of CDW materials	Identifies multiple C&D waste classifications under site-like conditions.	Requires robust datasets, image quality control, and site-level deployment capability.
Liu et al. [32]	System dynamics model	Simulates environmental, economic, and social impacts of C&D waste governance	Supports decision-making for CDW environmental assessment	Provides a dynamic assessment model for C&D waste impacts in Guangzhou.	Model assumptions and local data availability may affect generalizability.
Di Maria et al. [31]	Integrated LCA and LCC	Compares CDW end-of-life scenarios	Supports high-quality recycling and policy decision-making	Combines environmental and economic evaluation of recycling and downcycling options.	Requires comprehensive cost and environmental inventory data.
Akanbi et al. [20]	BIM-based whole-life performance estimator	Estimates salvage performance of building components from the design stage	Supports material recovery, reuse, and end-of-life planning	Enables early appraisal of salvage potential for structural components.	Requires detailed BIM information and assumptions about component lifespan and recoverability.
Akanbi et al. [51]	Disassembly and Deconstruction Analytics System	Assesses end-of-life performance and deconstruction potential	Supports design for disassembly and circular building planning	Provides BIM-enabled analytics for disassembly and deconstruction decisions.	Adoption depends on BIM maturity and integration into design decision-making.
Kurniawan et al. [53]	Digital waste recycling technologies	Supports digitalization-based recycling and resource recovery	Links Industry 4.0 technologies with circular waste systems	Shows how digital technologies can add economic value to recycled waste and support zero-waste goals.	Focus is broader than CDW and requires contextual adaptation for construction waste systems.
Majchrowska et al. [52]	Deep learning-based waste detection	Detects and classifies waste in natural and urban environments	Supports automation and higher recycling efficiency	Provides benchmarks and methods for automatic waste detection.	Not CDW-specific, but relevant for automated waste recognition and classification methods.

Implementation Pathways and Future Research Directions

The fourth synthesis theme integrates evidence on implementation pathways and future research directions. Table 4 shows that circular CDW implementation requires coordinated pathways across policy, procurement, design, market development, stakeholder collaboration, and digital transformation. Policy pathways include landfill restrictions, recycling targets, quality standards, green public procurement, and incentives for secondary material use. Alhola et al. [25] show that public procurement can create demand for circular products, while Bao et al. [54] demonstrate that procurement innovation and public-private partnership can support circular CDW projects. Giorgi et al. [18] and Guerra and Leite [17] further indicate that policy and stakeholder awareness must be aligned if circular strategies are to move beyond isolated pilot practices.

Implementation also depends on design and business-model pathways. Gálvez-Martos et al. [1] and Ghaffar et al. [46] emphasize integrated value-chain management and resource recovery, while Eberhardt et al. [13] locate circularity in design strategies that slow, narrow, and close loops. Adams et al. [14] highlight the need for systems thinking and circular business models that retain residual material value. Future research should therefore move beyond descriptive accounts of recycling and focus on empirical validation of integrated implementation models. Priorities include comparative regional studies, circular procurement models, market mechanisms for secondary materials, digital material passports, blockchain-enabled traceability, business models for component reuse, lifecycle carbon assessment, and performance indicators linking circular strategies to measurable outcomes (**Figure 5** and **Figure 6**).

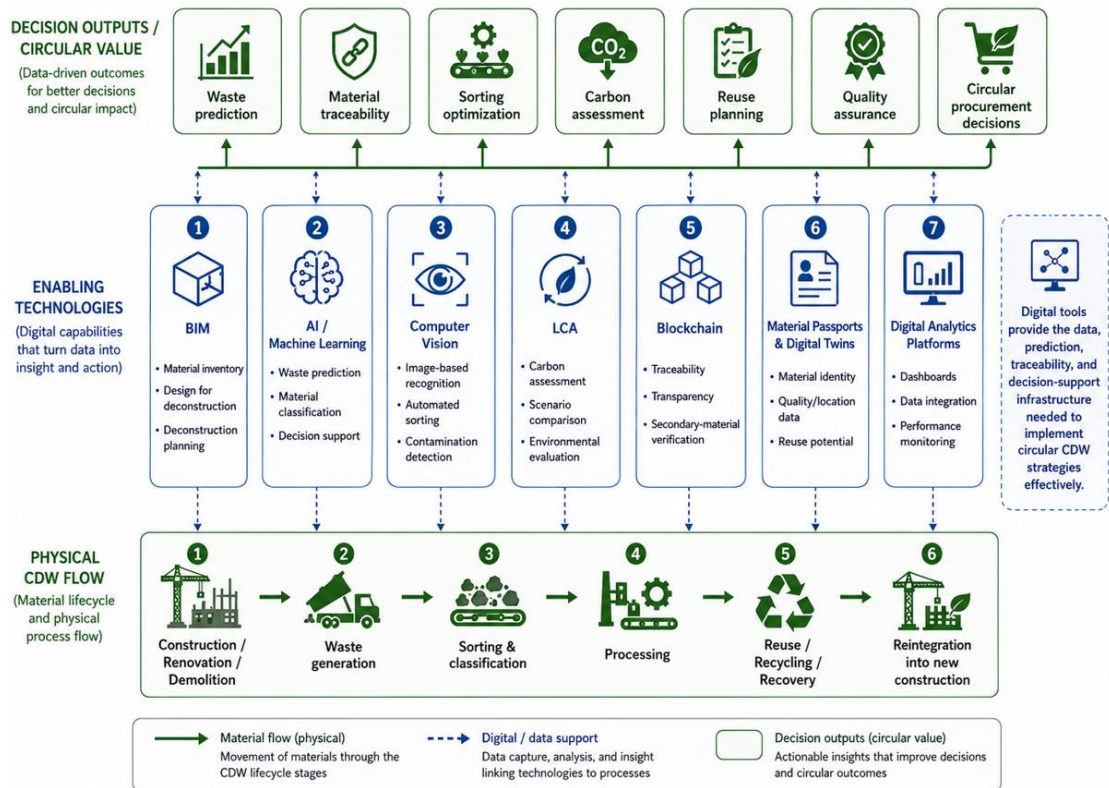


Figure 5. Conceptual foundation of circular construction and demolition waste management.

Table 4. Essential summary of implementation pathways and future research directions

References	Implementation pathway	Main actors involved	Mechanism or intervention	Expected circular outcome	Future research direction
Gálvez-Martos et al. [1]	Value-chain CDW best practices	Designers, contractors, waste managers, policymakers	Reduce waste generation, improve logistics, increase reuse and recycling quality	Higher resource efficiency and lower environmental impact across the CDW chain	Comparative studies on how best practices perform across different regulatory and market contexts.
Alhola et al. [25]	Circular public procurement	Public authorities, municipalities, suppliers, contractors	Procurement criteria for reuse, recycling, product life extension, and circular business models	Increased market demand for circular products and secondary materials	Research on procurement models specifically targeting CDW recovery and circular construction markets.
Bao et al. [54]	Procurement innovation and PPP	Government, private contractors, waste-service providers	Public-private partnership and relational contracting for CDW circularity	Improved delivery of CDW circular economy projects	Further work on transparency, risk allocation, value-for-money, and governance models in CDW procurement.
Bao and Lu [47]	Circularity development in fast-emerging economies	Local government, recycling firms, construction sector	Rapid development of CDW circular economy systems through policy and infrastructure	Improved CDW treatment and circularity under rapid urbanization	Cross-city comparison of circular CDW governance models in emerging economies.
Ghaffar et al. [46]	Integrated resource recovery pathway	Construction stakeholders, waste operators, policymakers	Reuse, recycling, and recovery supported by stakeholder	Transition toward circular construction and resource recovery	Longitudinal studies on the effectiveness of integrated CDW management systems.

Guerra and Leite[17]	Stakeholder awareness and enabler pathway	AEC stakeholders in the United States	awareness and management integration Awareness-building, identification of challenges, and enabling strategies	Increased readiness for transition from linear to circular construction	Empirical studies measuring how awareness and enablers translate into project-level circular outcomes.
Giorgi et al. [18]	Policy-practice alignment pathway	Policymakers, building stakeholders, industry organizations	Alignment of circularity strategies, barriers, and drivers across European countries	Better uptake of circular strategies in building-sector practice	Research on how national policies interact with stakeholder behavior and market readiness.
Eberhardt et al. [13]	Circular design pathway	Designers, architects, engineers, developers	Design strategies that slow, narrow, and close material loops	Reduced waste generation and improved material retention from early design stages	More empirical assessment of environmental performance from circular design strategies.
Adams et al. [14]	Business model and systems pathway	Construction firms, clients, supply-chain actors	Circular business models and systems thinking for retaining material residual value	Movement beyond recycling toward value retention and circular supply chains	Future studies should test circular business models in real construction and demolition projects.



Figure 6. Conceptual foundation of circular construction and demolition waste management.

Discussion

The findings show that circular CDW management is a systemic transition rather than a technical recycling challenge. Although recycling remains important, the strongest circular strategies are those that intervene earlier in the lifecycle by preventing waste, designing for disassembly, enabling component reuse, and preserving material value. This supports circular

economy theory that distinguishes between closing loops through recycling and slowing or narrowing loops through reuse, lifetime extension, material efficiency, and design optimization [29-34]. The reviewed evidence indicates that CDW circularity is strongest when design, procurement, demolition, treatment, and secondary-material markets are planned together rather than addressed as separate project phases.

A key implication is that circular CDW strategies should be evaluated by value retention, not only by recovery rates. High recovery percentages can still mask downcycling, contamination, low-value use, or displacement of environmental burdens. Studies on recycled aggregates, recycled cementitious materials, waste ceramics, geopolymers, recycled cement, and supplementary cementitious materials demonstrate that secondary materials can support lower-impact construction, but only when technical performance, durability, processing energy, and market acceptance are considered [36], [55-59]. Therefore, circular CDW management should integrate engineering performance with environmental and economic assessment.

The barrier synthesis suggests that circular CDW management often fails at the interface between policy ambition and practical implementation. Regulations may encourage recycling or landfill diversion, but circularity requires enforceable standards, quality assurance, procurement demand, infrastructure, and stakeholder coordination. Economic barriers remain powerful because secondary materials must compete with low-cost virgin materials while bearing additional costs for sorting, testing, transport, certification, and market development. Organizational barriers are equally important, especially in fragmented construction supply chains where design decisions, procurement criteria, site practices, and demolition planning are controlled by different actors. These findings are consistent with wider circular supply-chain research showing that barriers are interconnected and require coordinated mitigation rather than isolated solutions [42,43].

Digital technologies offer a promising but conditional pathway. BIM, deep learning, LCA, system dynamics, blockchain, and digital platforms can improve material prediction, classification, traceability, and decision support. However, the reviewed literature suggests that digital tools remain unevenly validated in real CDW contexts. Deep learning-based waste detection and construction-waste classification require large and representative datasets; BIM-based deconstruction analytics require detailed models and consistent asset information; blockchain-enabled traceability requires governance agreements and trustworthy data input [21,23,52,60]. Thus, digital transformation should be treated as an implementation pathway that depends on data governance, interoperability, standards, and user adoption rather than as a stand-alone technological fix.

The review also highlights the importance of integrating circular CDW management with broader sustainability and urban transitions. Building materials contribute substantially to lifecycle greenhouse gas emissions, and material efficiency strategies can reduce emissions through reuse, substitution, lifetime extension, and recycling [8,9]. Urban material-stock analysis further shows that demolition waste is linked to accumulated building stocks, renovation cycles, and future replacement flows [39,40]. Circular CDW management should therefore be connected to low-carbon construction, sustainable cities, public procurement, and industrial symbiosis. Such integration can increase the policy relevance of CDW circularity and align it with climate, resource-efficiency, and sustainable development goals.

The evidence base has several limitations. First, much of the literature is conceptual, review-based, or case-specific, limiting generalizability across regulatory and market contexts. Second, empirical validation of digital technologies in real construction and demolition projects remains limited. Third, studies often focus on recycling and material recovery, while higher-value strategies such as reuse, adaptive reuse, design for disassembly, and business model

innovation receive less quantified performance evidence. Fourth, social, organizational, and behavioral dimensions are still less developed than technical and environmental analyses. Future research should therefore combine project-level empirical studies, lifecycle assessment, cost-benefit analysis, stakeholder behavior research, and digital technology validation. The most valuable future work will be integrative: it should examine how policy, market demand, digital tools, material standards, and business models interact to produce measurable circular outcomes.

Conclusion

This systematic literature review synthesized circular economy strategies for construction and demolition waste management by integrating evidence on strategies, barriers, technologies, and implementation pathways. The review shows that circular CDW management requires more than recycling; it depends on waste prevention, design for disassembly, selective demolition, component reuse, recycled-content procurement, high-quality recovery, lifecycle assessment, and coordinated governance. Major barriers remain technical, economic, regulatory, organizational, behavioral, and informational. These barriers constrain secondary-material markets, stakeholder coordination, material quality assurance, and adoption of circular practices. Digital technologies such as BIM, artificial intelligence, deep learning, blockchain, material passports, and life-cycle assessment can improve prediction, traceability, classification, and circular decision-making, but their effectiveness depends on reliable data, interoperability, institutional readiness, and project-level validation. The review contributes an integrated framework that links circular strategies with barriers, technological enablers, and implementation pathways. Future research should focus on comparative regional studies, empirical validation of digital tools, circular business models, procurement mechanisms, performance indicators, and policy effectiveness. Ultimately, the transition toward circular CDW management requires transforming construction waste from an end-of-life problem into a lifecycle resource-flow challenge.

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contribution Statement

Muzakkir Putera: Conceptualization, Methodology, Software. **Newton:** Data curation, Writing- Original draft preparation. **Zulfan:** Visualization, Investigation. **Husein:** Supervision. **Nazla:** Writing- Reviewing and Editing. **Banthasith Vongphuthone:** Conceptualization, Methodology.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

Not required.

References

- [1] J. L. Gálvez-Martos, D. Styles, H. Schoenberger, and B. Zeschmar-Lahl, 2018, Construction and demolition waste best management practice in Europe, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2018.04.016.
- [2] B. Huang, X. Wang, and H. Kua, 2018, Construction and demolition waste management in China through the 3R principle, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2017.09.029.
- [3] A. Akhtar and A. K. Sarmah, 2018, Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2018.03.085.
- [4] P. Villoria Sáez and M. Osmani, 2019, A diagnosis of construction and demolition waste generation and recovery practice in the European Union, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2019.118400.
- [5] P. Ghisellini, M. Ripa, and S. Ulgiati, 2018, Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector: A literature review, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2017.11.207.
- [6] P. Ghisellini, X. Ji, G. Liu, and S. Ulgiati, 2018, Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2018.05.084.
- [7] G. Foster, 2020, Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2019.104507.
- [8] E. G. Hertwich, S. Ali, and L. Ciacci, 2019, Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics: A review, *Environmental Research Letters*, doi: 10.1088/1748-9326/abofe3.
- [9] X. Zhong, S. Deetman, A. Tukker, and P. Behrens, 2021, Global greenhouse gas emissions from residential and commercial building materials and mitigation strategies to 2060, *Nat. Commun.*, doi: 10.1038/s41467-021-26212-z.
- [10] M. Ma, V. W. Y. Tam, K. N. Le, and W. Li, 2020, Challenges in current construction and demolition waste recycling: A China study, *Waste Management*, doi: 10.1016/j.wasman.2020.09.030.
- [11] R. Minunno, T. O'Grady, G. M. Morrison, and R. L. Gruner, 2018, Strategies for applying the circular economy to prefabricated buildings, *Buildings*, doi: 10.3390/buildings8090125.
- [12] R. Minunno, T. O'Grady, G. M. Morrison, R. L. Gruner, and M. Colling, 2020, Exploring environmental benefits of reuse and recycle practices: A circular economy case study of a modular building, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2020.104855.
- [13] L. C. M. Eberhardt, M. Birkved, and H. Birgisdottir, 2022, Building design and construction strategies for a circular economy, *Architectural Engineering and Design Management*, doi: 10.1080/17452007.2020.1781588.
- [14] K. T. Adams, M. Osmani, T. Thorpe, and J. Thornback, 2017, Circular economy in construction: Current awareness, challenges and enablers, *Proceedings of the Institution of Civil Engineers: Waste and Resource Management*, doi: 10.1680/jwarm.16.00011.
- [15] A. Mahpour, 2018, Prioritizing barriers to adopt circular economy in construction and demolition waste management, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2018.01.026.
- [16] M. Bilal, K. I. A. Khan, M. J. Thaheem, and A. R. Nasir, 2020, Current state and barriers to the circular economy in the building sector: Towards a mitigation framework, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2020.123250.
- [17] B. C. Guerra and F. Leite, 2021, Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and enablers, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2021.105617.
- [18] S. Giorgi, M. Lavagna, and A. Campioli, 2022, Drivers and barriers towards circular economy in the building sector: Stakeholder interviews and analysis of five European countries policies and practices, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2022.130395.
- [19] M. R. Munaro, S. F. Tavares, and L. Bragança, 2023, A review on barriers, drivers, and stakeholders towards the circular economy: The construction sector perspective, *Cleaner and Responsible Consumption*, doi: 10.1016/j.clrc.2023.100107.
- [20] L. A. Akanbi et al., 2018, Salvaging building materials in a circular economy: A BIM-based whole-life performance estimator, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2017.10.026.
- [21] L. A. Akanbi, L. O. Oyedele, and O. O. Akinade, 2020, Deep learning model for demolition waste prediction in a circular economy, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2020.122843.
- [22] S. Çetin, C. De Wolf, and N. Bocken, 2021, Circular digital built environment: An emerging framework, *Sustainability*, doi: 10.3390/su13116348.
- [23] P. Davis, F. Aziz, M. T. Newaz, W. Sher, and L. Simon, 2021, The classification of construction waste material using a deep convolutional neural network, *Autom. Constr.*, doi: 10.1016/j.autcon.2020.103481.
- [24] J. L. Hao, B. Cheng, and W. Lu, 2020, Carbon emission reduction in prefabrication construction during materialization stage: A BIM-based life-cycle assessment approach, *Science of the Total Environment*, doi: 10.1016/j.scitotenv.2020.137870.
- [25] K. Alhola, S. O. Ryding, H. Salmenperä, and N. J. Busch, 2019, Exploiting the potential of public procurement: Opportunities for circular economy, *J. Ind. Ecol.*, doi: 10.1111/jiec.12770.
- [26] J. L. K. Nußholz, F. Nygaard Rasmussen, and L. Milios, 2019, Circular building materials: Carbon saving potential and the role of business model innovation and public policy, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2018.10.036.

- [27] W. Fei, A. Opoku, and K. Agyekum, 2021, The critical role of the construction industry in achieving the sustainable development goals (SDGs): Delivering projects for the common good, *Sustainability*, doi: 10.3390/su13169112.
- [28] O. E. Ogunmakinde, W. Sher, and K. Maund, 2022, Contributions of the circular economy to the UN sustainable development goals through sustainable construction, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2021.106023.
- [29] D. Reike, W. J. V Vermeulen, and S. Witjes, 2018, The circular economy: New or refurbished as CE 3.0? Exploring controversies in the conceptualization of the circular economy, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2017.08.027.
- [30] M. Ranjbari, Z. Shams Esfandabadi, and M. C. Zanetti, 2021, Two decades of research on waste management in the circular economy: Insights from bibliometric, text mining, and content analyses, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2021.128009.
- [31] A. Di Maria, J. Eyckmans, and K. Van Acker, 2018, Downcycling versus recycling of construction and demolition waste: Combining LCA and LCC to support sustainable policy making, *Waste Management*, doi: 10.1016/j.wasman.2018.01.028.
- [32] J. Liu, Y. Yi, and X. Wang, 2020, An environmental assessment model of construction and demolition waste based on system dynamics: A case study in Guangzhou, *Environmental Science and Pollution Research*, doi: 10.1007/s11356-019-07107-5.
- [33] A. K. Feroz, H. Zo, and A. Chiravuri, 2021, Digital transformation and environmental sustainability: A review and research agenda, *Sustainability*, doi: 10.3390/su13031530.
- [34] P. Morsetto, 2020, Targets for a circular economy, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2019.104553.
- [35] A. Mayer, W. Haas, and D. Wiedenhofer, 2019, Measuring progress towards a circular economy: A monitoring framework for economy-wide material loop closing in the EU28, *J. Ind. Ecol.*, doi: 10.1111/jiec.12809.
- [36] C. Thomas, J. Setién, and J. A. Polanco, 2020, Macro- and micro-properties of multi-recycled aggregate concrete, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2019.118843.
- [37] L. W. Zhang, A. O. Sojobi, and V. K. R. Kodur, 2019, Effective utilization and recycling of mixed recycled aggregates for a greener environment, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2019.07.075.
- [38] A. Stephan and A. Athanassiadis, 2017, Quantifying and mapping embodied environmental requirements of urban building stocks, *Build. Environ.*, doi: 10.1016/j.buildenv.2016.11.043.
- [39] A. Stephan and A. Athanassiadis, 2018, Towards a more circular construction sector: Estimating and spatialising current and future non-structural material replacement flows, *Resour. Conserv. Recycl.*, doi: 10.1016/j.resconrec.2017.09.022.
- [40] S. Deetman, S. Marinova, and E. van der Voet, 2020, Modelling global material stocks and flows for residential and service sector buildings towards 2050, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2019.118658.
- [41] D. Wiedenhofer, T. Fishman, C. Lauk, W. Haas, and F. Krausmann, 2019, Integrating material stock dynamics into economy-wide material flow accounting: Concepts, modelling, and global application for 1900–2050, *Ecological Economics*, doi: 10.1016/j.ecolecon.2018.09.020.
- [42] N. Tura, J. Hanski, and T. Ahola, 2019, Unlocking circular business: A framework of barriers and drivers, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2018.11.202.
- [43] I. Kazancoglu, Y. Kazancoglu, E. Yarimoglu, and A. Kahraman, 2020, A conceptual framework for barriers of circular supply chains for sustainability in the textile industry, *Sustainable Development*, doi: 10.1002/sd.2100.
- [44] S. A. R. Khan, A. Razzaq, Z. Yu, and S. Miller, 2021, Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability, *Bus. Strategy Environ.*, doi: 10.1002/bse.2853.
- [45] I. Laskurain-Iturbe, G. Arana-Landín, B. Landeta-Manzano, and N. Uriarte-Gallastegi, 2021, Exploring the influence of industry 4.0 technologies on the circular economy, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2021.128944.
- [46] S. H. Ghaffar, M. Burman, and N. Braimah, 2020, Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2019.118710.
- [47] Z. Bao and W. Lu, 2020, Developing efficient circularity for construction and demolition waste management in fast emerging economies: Lessons learned from Shenzhen, China, *Science of the Total Environment*, doi: 10.1016/j.scitotenv.2020.138264.
- [48] S. Jain, S. Singhal, N. K. Jain, and K. Bhaskar, 2020, Construction and demolition waste recycling: Investigating the role of theory of planned behavior, institutional pressures and environmental consciousness, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2020.121405.
- [49] R. Jin, B. Li, T. Zhou, D. Wanatowski, and P. Piroozfar, 2017, An empirical study of perceptions towards construction and demolition waste recycling and reuse in China, *Resour. Conserv. Recycl.*, vol. 126, pp. 86–98, doi: 10.1016/j.resconrec.2017.07.034.
- [50] D. Densley Tingley, S. Cooper, and J. Cullen, 2017, Understanding and overcoming the barriers to structural steel reuse, a UK perspective, *J. Clean. Prod.*, vol. 148, pp. 642–652, doi: 10.1016/j.jclepro.2017.02.006.
- [51] L. A. Akanbi, L. O. Oyedele, and O. O. Akinade, 2019, Disassembly and deconstruction analytics system (D-DAS) for construction in a circular economy, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2019.03.172.
- [52] S. Majchrowska, A. Mikołajczyk, and M. Ferlin, 2022, Deep learning-based waste detection in natural and urban environments, *Waste Management*, doi: 10.1016/j.wasman.2021.12.001.
- [53] T. A. Kurniawan, 2022, Unlocking digital technologies for waste recycling in Industry 4.0 era: A transformation towards a digitalization-based circular economy in Indonesia, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2022.131911.

- [54] Z. Bao, W. M. W. Lee, and W. Lu, 2019, Procurement innovation for a circular economy of construction and demolition waste: Lessons learnt from Suzhou, China, *Waste Management*, doi: 10.1016/j.wasman.2019.08.031.
- [55] R. P. Singh, 2023, Fly ash, GGBS, and silica fume based geopolymer concrete with recycled aggregates: Properties and environmental impacts, *Constr. Build. Mater.*, doi: 10.1016/j.conbuildmat.2023.131168.
- [56] V. Sousa and J. A. Bogas, 2021, Comparison of energy consumption and carbon emissions from clinker and recycled cement production, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2021.127277.
- [57] M. Samadi, G. F. Huseien, and H. Mohammadhosseini, 2020, Waste ceramic as low cost and eco-friendly materials in the production of sustainable mortars, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2020.121825.
- [58] R. Snellings, 2023, Future and emerging supplementary cementitious materials, *Cem. Concr. Res.*, doi: 10.1016/j.cemconres.2023.107199.
- [59] D. Qian, 2020, A novel development of green ultra-high performance concrete (UHPC) based on appropriate application of recycled cementitious material, *J. Clean. Prod.*, doi: 10.1016/j.jclepro.2020.121231.
- [60] B. Wang, W. Luo, A. Zhang, Z. Tian, and Z. Li, 2020, Blockchain-enabled circular supply chain management: A system architecture for fast fashion, *Comput. Ind.*, doi: 10.1016/j.compind.2020.103324.