

Advancing The Circular Economy In Construction: Recycling And Reusing Construction And Demolition Waste For Sustainable Building Development

Ahmed Adeleye SALAMI 1, Steve JAYEOBA 2, Adedamola Ibukunoluwa ADENIJI 3, Oluyemi Emmanuel BABATUNDE 4, Timothy AMUSAN

¹Dept of Architecture. Lead City University, , City, Nigeria
Leye05@gmail.com

²Dept. name of organization, name of organization, City, Country
e-mail address

³Dept. name of organization, name of organization, City, Country
e-mail address

⁴Dept. name of organization, name of organization, City, Country
e-mail address

Abstract: *The construction sector consumes large quantities of natural resources while generating substantial volumes of construction and demolition waste (CDW), creating linked concerns around landfill pressure, resource depletion and emissions. This study examines how circular economy (CE) principles can improve the recovery, recycling and reuse of CDW for sustainable building development. It adopts a structured qualitative literature-review methodology, drawing together the academic and practice-oriented sources cited in the study and comparing evidence on lifecycle planning, design for disassembly, selective demolition, recycled aggregates, reusable construction systems, digital traceability, policy instruments and secondary-material markets. The review shows that circular performance is strongest when waste prevention begins at the design and procurement stages and is supported by source segregation, reliable processing, quality assurance and pathways for reintegrating recovered materials into new construction. Across the reviewed evidence, recycled materials and selective recovery techniques can reduce dependence on virgin resources and landfill disposal, although performance and economic outcomes vary with material quality, market conditions, regulation, technical capacity and project context. The analysis also identifies persistent barriers, including fragmented responsibilities, uncertain demand for secondary materials, weak enforcement, limited finance, inconsistent standards and negative perceptions of recovered products. The study concludes that recycling alone is insufficient, a credible transition to circular construction requires coordinated action across the full building lifecycle, supported by design-for-reuse principles, collaborative supply chains, transparent assessment tools and enabling policy. It therefore recommends phased implementation that combines immediate improvements in segregation, procurement and quality control with longer-term development of digital material tracking, secondary-material markets, reusable systems and clearer regulatory incentives.*

Keywords— circular economy, construction and demolition waste, waste management, material recovery, sustainable construction.

1. INTRODUCTION

Construction is fundamental to economic growth and urban development, but the sector also places heavy pressure on material resources and waste-management systems. Construction and demolition waste (CDW) includes materials such as concrete, masonry, timber, reinforcement and other products discarded during construction, renovation and demolition. In many countries, CDW is estimated to represent approximately 30–40% of total solid waste, creating significant demands on landfill capacity while also contributing to resource depletion and greenhouse-gas emissions (Papamichael et al., 2023; Purchase et al., 2022). These impacts are intensified by the conventional linear pattern in which resources are extracted, transformed into building products, used and ultimately discarded, even where a substantial proportion of their material value could potentially be retained.

Circular economy (CE) offers a different basis for organising construction activity. Rather than treating waste management as an end-of-life task, CE seeks to preserve the usefulness and value of materials for as long as practicable through waste prevention, direct reuse, recycling, recovery and regeneration. Within construction, this means considering material choices, adaptability, dismantling, recovery and future reuse from the earliest stages of a project, rather than waiting until demolition to decide what can be salvaged (López Ruiz et al., 2020; Oluleye et al., 2022). This broader lifecycle perspective can also create economic value through reduced disposal costs, more efficient material use, new recovery markets and employment opportunities. It aligns with the objectives of SDG 11 on sustainable cities and communities, SDG 12 on responsible consumption and production, and SDG 13 on climate action (Ogunmakinde et al., 2022).

The importance of this shift is therefore both environmental and operational. Decisions taken during briefing, design, specification and procurement influence whether building

components can later be repaired, adapted, separated and reused without excessive loss of value. End-of-life recycling remains important, but it is only one part of a circular strategy. A more complete approach also seeks to prevent avoidable waste, extend service life, facilitate future deconstruction and create reliable routes through which recovered materials can return to productive use. This study consequently focuses on the relationship between recycling and reuse practices, design decisions, material-recovery systems, market conditions and governance arrangements across the construction lifecycle.

1.1 RESEARCH OBJECTIVES

This study pursues four linked objectives. It critically reviews and synthesises research, industry-oriented evidence and policy-related material on recycling and reuse in CDW management; examines practical approaches such as design for disassembly, selective demolition, material processing, reusable systems and circular supply-chain models; Analyses the regulatory, economic, technical, organisational and socio-cultural factors that restrict or enable adoption; and uses the combined evidence to develop an evidence-based pathway for more sustainable building practice, including practical and policy-oriented actions that can support a transition towards circular construction.

1.2 RESEARCH QUESTIONS

Correspondingly, the review is guided by four research questions: what conceptual frameworks and research trends currently shape the application of CE principles to CDW; which practical recycling, reuse, recovery and design strategies have been applied and what does the reported evidence indicate about their performance; what interconnected barriers and enabling conditions influence adoption across different economic and institutional settings; and which assessment approaches, policy measures and implementation priorities can support effective, scalable and sustainable circular construction? These questions directly reflect the four objectives and provide the organising logic for the review and synthesis that follow.

1.3 METHODOLOGY

The study adopts a structured qualitative literature-review and comparative-synthesis design. Its evidence base consists of the peer-reviewed studies, review papers and practice-oriented publications cited in this report on circular construction, CDW management, material recovery, design for disassembly, selective demolition, recycled aggregates, digital tools, reusable formwork and wood recovery. No primary field survey, laboratory experiment or new lifecycle model is presented as part of this study. Instead, the research draws on published empirical and conceptual evidence and uses that evidence to explain how circular principles are being interpreted, tested and implemented across different construction contexts. This distinction is important because the numerical performance values discussed later in the report are reported findings from cited studies rather than measurements generated by the present research.

The review process is organised around the study objectives. First, the literature is examined for conceptual definitions and lifecycle frameworks that explain how CE principles can be embedded from design through end-of-life recovery. Second, practical evidence is grouped according to major intervention areas, including waste prevention, design for disassembly, prefabrication, selective demolition, sorting, recycled-aggregate production, reusable temporary systems and secondary-material reintegration. Third, the studies are compared across recurring implementation conditions such as policy, cost, technical quality, logistics, organisational coordination, stakeholder knowledge and market acceptance. Finally, evidence on environmental, economic and social assessment is brought together to identify practical pathways and unresolved research needs. The approach is therefore thematic and comparative rather than a simple sequence of source summaries.

Because the reviewed studies use different methods, project types, indicators and geographical settings, the synthesis does not treat their results as directly interchangeable. Instead, it identifies areas of convergence, contrasts context-dependent findings and retains the qualifications reported in the literature. This helps avoid overstating the generalisability of individual case studies or laboratory results. The methodology also gives particular attention to implementation in emerging economies because the literature identifies differences in enforcement capacity, finance, infrastructure and market development that can influence whether circular practices that are technically feasible can also become commercially and institutionally viable (Bhavsar et al., 2023; Awodele et al., 2025).

2. LITERATURE REVIEW

The literature on CE and CDW has expanded from a narrow emphasis on recycling towards a broader concern with how material value can be retained throughout a building's lifecycle. For this reason, the review is organised thematically. It begins with conceptual foundations and lifecycle frameworks, then examines barriers to implementation, practical strategies and case evidence, environmental and economic implications, assessment methods and a pathway towards sustainable building practice. This structure provides a clear progression from theoretical understanding to practical application and identification of research gaps.

2.1 CONCEPTUAL FOUNDATIONS AND FRAMEWORKS

A central argument in the literature is that circular construction cannot be achieved by concentrating only on demolition-stage recycling. CE principles have to influence decisions made before construction, during project delivery, throughout use and adaptation, and at end of life. López Ruiz et al. (2020) synthesise this lifecycle perspective through an integrative model of CE strategies distributed across five

phases. Their framework is useful because it connects design choices with later recovery opportunities and shows that the quality of end-of-life outcomes is partly determined many years earlier.

1. **Pre-construction phase** (design and planning): the emphasis is on preventing waste and preserving future material value before construction begins.

- Design for disassembly and adaptability (DfD): components and connections are planned so that buildings can be altered, deconstructed and reused with less damage and material loss.
- Selection of durable, recyclable and lower-impact materials: specifications, material passports and lifecycle information are used to improve the prospects for maintenance, recovery and future reuse.
- Modular and prefabricated design: standardised elements can improve dimensional control, reduce offcuts and make components easier to replace, relocate or reuse.
- Early lifecycle planning: building information modelling (BIM) and related tools can support scenario testing, material tracking and consideration of end-of-life options during design.

2. **Construction and renovation phase:** circular practice focuses on avoiding unnecessary waste and protecting the quality of materials that do become surplus.

- Efficient material management: accurate ordering, prefabrication and coordinated delivery can reduce surplus stock, handling damage and avoidable disposal.
- On-site sorting and segregation: separating material streams at source limits contamination and increases the likelihood of higher-value recycling or direct reuse.
- Reusable temporary works: repeated use of items such as formwork and scaffolding reduces dependence on single-use resources during project delivery.

3. **Collection and distribution phase:** recovered materials require organised logistics if they are to remain usable and reach potential buyers or subsequent projects.

- Separate collection systems should reflect the different handling, contamination and storage requirements of individual CDW fractions.
- Secondary-material markets and reverse supply chains are needed to connect recovered materials with storage, processing, trading and future construction demand.
- Testing, certification and transparent quality assurance can reduce uncertainty and strengthen confidence in reclaimed and recycled products.

4. **End-of-life phase** (demolition and deconstruction): the priority shifts from destructive removal towards controlled recovery wherever this is technically and economically practicable.

- Selective demolition and deconstruction allow valuable components and cleaner material fractions to be separated before they are mixed or damaged.
- Direct-reuse planning identifies intact elements, including beams, panels and other recoverable

components, for reuse before lower-value recycling is considered.

5. **Material-recovery and production phase:** Materials that cannot be directly reused are processed so that they can re-enter manufacturing or construction cycles.

- Advanced processing and upcycling can convert mineral and other CDW streams into secondary aggregates, components or alternative products with greater usable value.
- Reintegration into new production closes the material loop by substituting suitable recovered content for part of the virgin resource input required by new construction.

All together, these lifecycle strategies move CE beyond the familiar 'reduce, reuse and recycle' sequence by showing how design, procurement, logistics, recovery and market development have to work as a connected system (López Ruiz et al., 2020; Oluleye et al., 2022; Papamichael et al., 2023). This framework also helps explain why recycling rates alone can give an incomplete picture of circularity: materials may be recycled at relatively low value even where better design could have enabled direct reuse, adaptation or remanufacture. Ginga et al. (2020) complements this systems point of view by concentrating on the practical relationship between material recovery and new-product manufacture. Their review follows CDW through source separation, sorting, cleaning, crushing and other processing stages, with particular attention to recycled aggregate. The important point is not simply that waste can be processed, but that recovered outputs need specifications, quality control and a destination within construction supply chains. Concrete, paving products and other applications demonstrate the technical potential for recovered mineral materials to return to use, while also showing that performance depends on the condition and consistency of the incoming waste stream.

This operational perspective is complemented by research that defines circular construction more broadly. Hasibuan et al. (2025) and Ossio et al. (2023) both argue that the concept involves coordinated change at several levels rather than an isolated improvement in waste treatment. Their work links technical systems with organisational collaboration, policy, market structures and wider social considerations. From this perspective, circularity becomes part of the construction system and its decision-making processes, not merely a characteristic of a recycled material.

Hasibuan et al. (2025) emphasise lifecycle integration and the need to connect project-level decisions with organisational and urban-scale systems. The main implications of this view include:

- Lifecycle continuity: circular decisions should begin with design for adaptability and recovery, continue through construction-stage waste prevention and extend to end-of-life reuse and recycling.
- Digital support: BIM, material passports and traceability tools can improve information continuity and help project teams understand where materials are, what condition they are in and how they might be recovered.

- Stakeholder coordination: clients, designers, contractors, demolition specialists, recyclers and policymakers need aligned responsibilities because no single actor controls the full material lifecycle.
- Urban and regional infrastructure: individual building projects depend on wider systems such as material banks, recovery facilities, reverse logistics and industrial-symbiosis opportunities.
- Higher-value circular strategies: reduction, direct reuse and remanufacture should be considered before lower-value recycling where technical, safety and economic conditions permit.
- Implementation enablers: standards, certification, performance metrics and viable business models can translate circular objectives into repeatable practice.

Ossio et al. (2023) extend this interpretation by treating circular construction as environmental, economic, social and cultural rather than purely material. Their synthesis suggests that design-for-circularity, modularity, material information and recovery processes need to be supported by policy alignment and value-chain reorganisation. It also draws attention to benefits such as employment and resilience alongside resource efficiency. Taken together, the two studies frame circular construction as multifaceted, whole-lifecycle and transformative: technical innovation matters, but sustained change also depends on governance, markets, professional practice and stakeholder behaviour.

BARRIERS AND CHALLENGES TO CIRCULAR ECONOMY IMPLEMENTATION

Despite a growing body of supportive evidence, CE adoption in construction remains uneven. The literature does not point to a single obstacle; instead, it describes a network of regulatory, economic, technical, organisational and social constraints that influence one another. Mahpour (2018), using multi-criteria decision analysis, groups major barriers into regulatory, economic, technical and organisational domains. Later studies reach a similar conclusion and show that the relative importance of individual barriers varies by market maturity, institutional capacity and project context (Ferriz-Papi et al., 2024; Bhavsar et al., 2023).

For analytical purposes, the barriers can be grouped into four broad categories: regulatory and institutional constraints; economic, financial, technical and operational constraints; organisational, behavioural and knowledge-related constraints; and social or cultural constraints. The categories are separated below for clarity, but their effects are frequently cumulative.

Regulatory and Institutional Barriers

Weak or inconsistent regulation is repeatedly identified as a major limitation. Policy statements on CDW may exist without measurable recovery targets, effective inspection, quality certification or incentives for secondary-material use. Mahpour (2018) notes that unclear requirements can leave selective demolition and recycled-content expectations voluntary or inconsistently applied, while Ferriz-Papi et al.

(2024) similarly identify fragmented regulation as a significant obstacle. When rules are uncertain, investors and contractors have less confidence that expenditure on sorting, processing and certification will be rewarded by stable demand.

Institutional capacity affects whether formal policy can be translated into routine practice. In emerging economies, Bhavsar et al. (2023) and Awodele et al. (2025) highlight challenges associated with limited enforcement, governance weaknesses and capacity constraints. Fragmentation can also occur in more developed systems where design, construction and waste-management responsibilities are divided among different agencies or contractual actors (Khalfan et al., 2026). The practical consequence is a broken chain of responsibility: one organisation may specify materials, another construct the building and a third manage demolition decades later, without a mechanism that preserves circular objectives across those transitions.

Economic and Financial Barriers

Economic decisions often favour the lowest immediate cost even when lifecycle savings might support a circular option. Selective demolition, careful sorting, storage and material testing can require additional time or initial expenditure, while virgin materials and conventional disposal may remain relatively cheap. Martin et al. (2024) and Purchase et al. (2022) identify uncertain secondary-material demand and market volatility as important constraints, and Mahpour (2018) notes that transport and processing costs can undermine the competitiveness of recycled aggregates where recovery facilities are distant or virgin resources are inexpensive.

Finance and risk perception are particularly important for smaller firms and developing markets. Access to capital for processing technology may be limited, while tax relief, procurement preferences or other green incentives may be absent (Awodele et al., 2025). Ferriz-Papi et al. (2024) also draw attention to the difficulty of establishing a convincing business case where warranties, liability and long-term material performance are perceived as uncertain. These conditions can create a circularity trap: weak demand reduces investment in quality and supply, while inconsistent supply and quality further weaken demand.

Technical and Operational Barriers

Technical confidence depends on the quality and consistency of recovered materials. Recycled CDW aggregates can differ in composition, strength and contamination level, particularly when demolition waste is mixed or poorly sorted. Bayram et al. (2025) and Ginga et al. (2020) indicate that appropriate processing and quality control are therefore essential before recycled materials can be considered for more demanding applications. Papamichael et al. (2023) likewise identify high-purity sorting and access to suitable processing facilities as continuing challenges in many regions.

Site and supply-chain logistics add another layer of difficulty. Circular practices may require additional space for

segregation, reliable collection schedules and manageable transport distances between the project, recovery facility and end user (She et al., 2024). Selective deconstruction can also conflict with programmes built around speed and low initial cost (Eberhardt et al., 2022). Digital tools such as BIM can improve planning and traceability, but adoption for circular material management is still uneven, meaning that information about materials is often lost between design, construction, operation and demolition (Rong et al., 2025).

Organisational, Behavioural and Knowledge Barriers

Some of the most persistent obstacles are organisational rather than purely technical. Limited knowledge of lifecycle costing, recovery options and circular procurement can lead stakeholders to view CE as an additional obligation instead of a source of long-term value (Oluleye et al., 2022; Hasibuan et al., 2025). Bhavsar et al. (2023) identify behavioural inertia among firms accustomed to linear practice, while Martin et al. (2024) point to limited client demand as a further reason why contractors and suppliers may be reluctant to change established methods.

Fragmented contracting arrangements reinforce these behaviours. Designers, contractors, demolition specialists, waste managers and recyclers often work within separate commercial structures and are rewarded for different short-term outcomes (Colorado et al., 2022). Where responsibilities for future recovery are not allocated early, material information may not be recorded, demolition may not be planned for reuse, and potential buyers may not be identified. Greater collaboration is therefore not simply desirable; it is a practical requirement for coordinating design decisions, future deconstruction, certification, logistics and market demand across the building lifecycle.

Social and Cultural Barriers

Market acceptance is also influenced by perception. Recycled and reclaimed products may be regarded as lower quality even where testing demonstrates acceptable performance. Nunes and Mahler (2024) note that preferences for new materials and resistance to unfamiliar construction methods can slow the development of secondary-material markets. Public and professional confidence is therefore linked to visible quality assurance, standards, demonstration projects and clear communication about appropriate applications rather than to technical performance alone.

Interconnections and Systemic Nature

The literature consistently shows that these barriers reinforce one another. Regulatory uncertainty increases financial risk; weak demand discourages investment in processing and certification; inadequate technical infrastructure can produce inconsistent materials; and inconsistent materials reinforce negative market perceptions. Emerging-economy studies add constraints such as limited infrastructure, weak enforcement and low stakeholder awareness (Bhavsar et al., 2023; Awodele et al., 2025), while Ferriz-Papi et al. (2024) and Martin et al. (2024) similarly emphasise the interaction

between market acceptance, fragmented supply chains and behavioural resistance.

For this reason, single measures are unlikely to produce broad change. A recycling plant cannot create a functioning circular market if incoming material is contaminated or buyers lack confidence; regulation cannot achieve recovery targets if enforcement, skills and infrastructure are absent; and design for disassembly has limited value if future deconstruction and resale channels do not exist. Effective implementation therefore requires mutually supporting interventions in policy, finance, technology, skills, information and market development (Oluleye et al., 2022; Ferriz-Papi et al., 2024).

STRATEGIES, PRACTICES AND EMPIRICAL EVIDENCE

The reviewed studies provide several practical responses to the barriers identified above. A recurring strategy is to move circular decisions upstream, particularly through design for deconstruction (DfD), modularity and reversible construction. Eberhardt et al. (2022) emphasise connections, component standardisation and material information that allow buildings to be dismantled with less damage. The value of these approaches lies in preserving future options: components that can be separated cleanly are more likely to be repaired, relocated or reused at a higher value than materials recovered only after destructive demolition.

Waste prevention during project delivery is equally important. She et al. (2024), drawing on Australian construction-project evidence and stakeholder perspectives, identify planning, material optimisation, on-site sorting and circular procurement requirements as practical measures for reducing CDW at source. Their findings suggest that front-end prevention can be more effective than relying on end-of-pipe recycling alone because it avoids the environmental and economic costs associated with generating, transporting and processing waste in the first place. Local regulation, organisational maturity and project-management practices influence the scale of improvement achieved.

Material performance remains central to market confidence. Purchase et al. (2022) examine recycled-aggregate concrete in relation to mechanical performance, environmental impacts and economic considerations, while Bayram et al. (2025) focus on selective demolition and the quality of recovered material streams. Considered together, these studies indicate that better source separation and processing can improve the reliability of recycled aggregates and that selective demolition can increase recovery while reducing contamination. Reported performance levels vary by material and application, so the evidence supports fit-for-purpose use and quality verification rather than a blanket assumption that all recycled materials can directly replace virgin products.

Case comparisons also show that technical feasibility is not enough on its own. Khalfan et al. (2026), for example, compare policy approaches in the United Kingdom and the United Arab Emirates and demonstrate the importance of institutional context. Rong et al. (2025) similarly show how BIM-enabled information can support circularity through

improved traceability. These studies reinforce a broader lesson from the review: the same technical strategy may perform differently where regulations, supply chains, disposal costs, digital capacity and secondary-material markets differ. Circular solutions therefore need to be adapted to local conditions rather than transferred without modification.

ENVIRONMENTAL, ECONOMIC IMPLICATIONS AND ASSESSMENT METHODS

Environmental and economic evaluation is necessary because circular strategies often involve trade-offs between additional effort at one stage and savings later in the lifecycle. Bayram et al. (2025) compare conventional and selective demolition using indicators that include emissions, energy use, landfill diversion and avoided virgin-resource consumption. Their evidence indicates that selective recovery and recycling can reduce embodied impacts and create financial value through avoided disposal and the use or sale of secondary materials. The scale of benefit, however, depends on the material stream, processing requirements, transport distances and the quality of the recovered output.

Circular CDW management also connects with wider sustainable-development objectives. Ogunmakinde et al. (2022) relate construction circularity to the UN Sustainable Development Goals by linking waste minimisation, reuse and recycling with responsible consumption, lower emissions and more resource-efficient cities. This broader framing is useful because it moves the discussion beyond tonnes of waste diverted from landfill. It also draws attention to employment, skills, material security and the capacity of urban development to reduce environmental burdens while maintaining economic activity.

Assessment Methods and Tools for Validation

Assessment methods translate broad claims about circularity into indicators that can be compared and monitored. Lovrenčić Butković et al. (2023) review available evaluation approaches and distinguish environmental methods such as life cycle assessment (LCA), economic approaches such as life cycle costing (LCC), social methods such as social life cycle assessment (SLCA), and integrated frameworks. Their review also identifies an important limitation: different projects often use different indicators and boundaries, making direct comparison difficult. Standardisation is therefore important if circular performance is to be benchmarked across projects and regions.

Balasbaneh et al. (2025) emphasise life cycle sustainability assessment (LCSA), which brings environmental, economic and social considerations together. By comparing scenarios with different levels of reuse, recycling or demolition selectivity, LCSA can reveal trade-offs that would be obscured by an assessment of initial cost or carbon alone. For example, a strategy may require greater expenditure at the beginning but generate lower lifecycle cost or better recovery outcomes later. Used carefully, integrated assessment provides a more defensible basis for selecting between

circular alternatives and for demonstrating whether stated sustainability objectives are actually being achieved.

Across the reviewed literature, the value of assessment is therefore twofold. First, it supports decision-making at project level by making consequences and trade-offs more visible. Second, it provides evidence for policy and market development by showing which interventions deliver consistent benefits. The current weakness is the absence of universally applied indicators, which limits comparison and can encourage selective reporting. Future circular-construction programmes should therefore define performance measures at the outset and retain the data needed for post-project evaluation.

PATHWAY TO SUSTAINABLE BUILDING PRACTICE

The evidence reviewed above suggests that a practical transition to circular construction should combine design-stage prevention with project-level recovery and longer-term market development. Two areas illustrate how this can work in practice: reusable formwork and prefabricated systems, and the recovery of timber and other bio-based construction materials. Both examples show that circularity is strongest when future reuse is anticipated in advance rather than treated as an improvised response to waste after it has been generated.

PREFABRICATION AND REUSABLE FORMWORK SYSTEMS IN CIRCULAR CONSTRUCTION

Reusable formwork and prefabricated components can reduce waste by replacing repeated consumption of short-life temporary materials with systems designed for multiple cycles. Conventional timber formwork may generate substantial offcuts and discarded panels where elements are damaged or used only a small number of times. Metal and reusable plastic systems can be redeployed across repeated pours or future projects, while prefabrication can improve dimensional control and reduce on-site cutting and waste (Cheng et al., 2022; Vandezande et al., 2024). The circular benefit is therefore created both by extending the service life of temporary works and by reducing the volume of material that becomes waste during construction.

Design for prefabrication and design for manufacture and assembly (DfMA) strengthen this approach because they allow component dimensions, connections, handling and future disassembly to be resolved during design. Reversible or standardised systems can support adaptation and reuse while reducing the dependence on wet, destructive or one-off construction processes. The reviewed evidence also indicates that digital planning can improve material efficiency and help teams coordinate manufacturing, delivery and assembly (Cheng et al., 2022). The exact environmental benefit varies by system and number of reuse cycles, so lifecycle assessment remains important when comparing reusable products with conventional alternatives.

Reusable plastic formwork, including systems produced through digital fabrication, provides a further example of how material choice and manufacturing method can support

circularity. Vandezande et al. (2024) discuss flexible formwork substitution in relation to material metabolism and risk reduction. The circular principle is that a durable system should be used repeatedly and, where appropriate recovery infrastructure exists, its material should remain capable of being processed again at the end of service. Such systems can also improve consistency and site efficiency, but their value depends on recovery arrangements, actual reuse rates and responsible material selection rather than on novelty alone.

RECOVERY AND REPROCESSING OF ON-SITE WOOD WASTE FOR SECONDARY CONSTRUCTION APPLICATIONS

Timber and bamboo waste illustrates a different circular pathway because parts of a discarded element may retain useful material properties even when the original construction purpose has ended. Instead of treating all offcuts, damaged formwork or dismantled timber as a single waste stream, circular practice begins with segregation and grading. Clean, reusable pieces should be separated from contaminated or degraded material so that the highest practicable value can be retained. Where direct reuse is not suitable, secondary processing can create other construction products and reduce demand for virgin timber.

Tighnavard Balasbaneh et al. (2026) link circular-economy principles with bio-based material applications and show the importance of matching recovered wood to technically appropriate secondary uses. The central logic is cascade utilisation: material is kept in productive use through successive applications before energy recovery or disposal is considered. This approach is consistent with the broader CE hierarchy discussed throughout the review because it gives priority to extending material life and avoiding premature loss of embodied resources.

Successful wood recovery still depends on practical controls. Construction timber may contain coatings, fasteners, moisture damage or other contamination, while quantities and dimensions can vary from project to project. Clear segregation procedures, weather-protected storage, grading, testing and dependable links with processors or manufacturers are therefore essential. Digital material records and selective deconstruction can improve traceability, but the wider market must also be capable of accepting recovered products. These requirements illustrate again that circularity depends on an organised system of design, logistics, quality assurance and demand rather than on material recovery in isolation.

CONCLUSION AND RESEARCH GAPS

The reviewed literature shows that circular construction has developed beyond a narrow concern with recycling and now addresses the wider question of how material value can be preserved across the building lifecycle. Evidence from lifecycle frameworks, recycled-material studies, selective demolition, design-for-disassembly research and circular assessment methods indicates that substantial environmental and resource benefits are possible when prevention, reuse, recovery and reintegration are planned together. The literature

also demonstrates that technical solutions alone do not guarantee adoption. Regulation, finance, organisational coordination, quality assurance, professional knowledge and market confidence all influence whether circular practices move from isolated projects into routine construction.

Several research gaps remain. Long-term evidence on the durability, repeated reuse and market performance of recovered materials is limited, particularly across different climatic and economic contexts and within emerging economies. Greater attention is also needed to the practical integration of BIM, digital twins, material passports and other traceability systems with real recovery markets. Although many studies propose frameworks, fewer demonstrate how policy, technology, procurement, business models and post-occupancy or post-demolition monitoring can be combined over time. More consistent key performance indicators are also required so that projects can be compared on a common basis rather than through isolated measures.

FURTHER AREA OF RESEARCH

Future research should therefore combine technical performance with evidence on lifecycle cost, stakeholder behaviour, user and market acceptance, governance and actual recovery outcomes after implementation. Comparative studies across different regulatory and market settings would help distinguish universal principles from context-specific solutions. Research in emerging economies is particularly important because constraints relating to enforcement, finance, infrastructure and informal material flows may change both the feasibility and the appropriate sequencing of circular interventions (Bhavsar et al., 2023; Awodele et al., 2025).

In practical terms, the transition should be staged. Near-term action can improve segregation, procurement requirements, quality control, reusable temporary works and material-recovery planning. Medium- and long-term action should strengthen design standards for adaptability and disassembly, digital traceability, recovery infrastructure, certification, secondary-material markets and policy incentives. The central conclusion of this study is therefore that circular construction is not achieved by a single recycling technology. It depends on coordinated decisions across the lifecycle and on institutions and markets that allow recovered materials to retain value. A credible implementation pathway must combine environmental ambition with technical verification, commercial realism and clearly allocated responsibility.

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