Review Article

Embedding Circularity in the Construction Supply Chain: A Systematic Review of Smart Procurement and Design practices

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Abstract

The transition to a circular economy in construction requires rethinking traditional supply chain dynamics, particularly in procurement and design. While sustainability efforts have largely focused on waste management and material recovery, early-stage interventions such as strategic procurement and circular design remain underexplored. This systematic literature review, guided by the PRISMA 2020 methodology, synthesizes insights from 32 research articles to assess the role of smart procurement and design practices in embedding circularity across the construction supply chain. The review identifies two key thematic clusters: (i) Dynamics in the sustainable supply chain for smart procurement and stakeholder collaboration and (ii) Circular design for resource optimization. Findings highlight critical barriers, including information asymmetry, fragmented decision-making, and short-term procurement approaches, which hinder the full integration of circular economy in the built environment. To address these gaps, the study proposes a conceptual framework to Embedding Circularity in the Construction Supply Chain, emphasizing early-stage interventions that align procurement and design decisions with long-term sustainability goals. Recommendations include policy incentives, technology innovation, and enhanced collaboration to strengthen circular economy adoption and reduce environmental impact in the built environment.

Keywords Smart Procurement, Circular Design, Sustainable Supply Chain, Circular Construction

Highlights

- Smart procurement and circular design are essential to embedding circularity upstream.
- Early-stage decisions lock in long-term impacts across construction supply chains.
- Digital tools and policies must align to overcome fragmentation and enable circular flows.

1 Introduction

The construction industry accounts for roughly one-quarter of global greenhouse gas emissions and consumes vast quantities of natural resources (Chen et al., 2021; Peris Mora, 2007). Traditional "take-make-dispose" Supply Chains (SCs) exacerbate resource depletion and waste generation, undermining efforts to mitigate climate change. Circular economy (CE) paradigms promise to close material loops and conserve value by emphasizing reuse, repair, and remanufacturing (Galle et al., 2019). Yet, implementation in construction remains uneven, with most initiatives focused on end-of-life waste management rather than upstream decision making (Pomponi & Moncaster, 2017).

Early-stage interventions, particularly in procurement and design, hold untapped potential for embedding circularity (Charef & Lu, 2021; Häkkinen et al., 2015). Smart procurement practices can steer material selection toward low-carbon, reusable products, while circular design approaches can facilitate disassembly, modularity, and adaptability (Yap et al., 2024). Embedding circular practices requires aligning early interventions with the stages of project development, where key decisions are made that lock in future material and environmental performance (Cambier et al., 2020). Despite growing recognition, smart procurement remains fragmented and poorly theorized during the design stages (Rathnayake et al., 2022). Embedding it from feasibility to detailed design offers a pathway to integrate circularity into construction SCs. (Cambier et al., 2020).

The feasibility design phase is the initial stage where the viability of a project is assessed, often focusing heavily on financial criteria (Shen et al., 2010). Some studies show that frequently during this stage environmental and social dimensions are not fully integrated (Shen et al., 2010). As the project moves into the developed and detailed design phases, the design becomes more defined (Rezaei et al., 2019). However, early stages still lack detailed material data, limiting traditional environmental assessment tools (Karlsson et al., 2021). When specifications are fixed, reusing design knowledge from past projects can improve efficiency and sustainability in detailed design (García de Soto et al., 2020).

Building on the above, smart procurement and design practices are emerging strategies that embed CE principles into the early stages of construction projects (Yap et al., 2024). Smart procurement integrates environmental criteria, life-cycle thinking, and digital tools to enable transparent and collaborative SCs. (Yevu et al., 2021). Meanwhile, design practices leverage technologies such as Building Information Modeling (BIM), and parametric modelling to optimize building performance from the outset (Rezaei et al., 2019). It emphasizes adaptability, modularity, and design for disassembly, enabling components to be reused or repurposed (Lima et al., 2023).

This review investigates what integrated smart procurement and design practices can embed circularity in construction SCs. By focusing on the following question, the aim is to align early smart procurement and design decisions with long-term circular objectives along the SCs.

RQ1: What smart procurement and design practices facilitate embedding circularity within the construction supply chain?

2 Methodology

The methodology for this review unfolds through five interlinked stages (Figure 1). In Stages I and II, the study first defined its research scope and objectives, targeting articles from 2015–2024. Two Boolean search strings reflecting CE, procurement, and design concepts were then applied to the Science direct, Scopus and Web of Science core collection. Retrieved records were consolidated into a single dataset, duplicates were removed, and metadata fields (titles, abstracts, keywords) were standardized, yielding 898 unique entries prepared for systematic screening (Marzi et al., 2024).

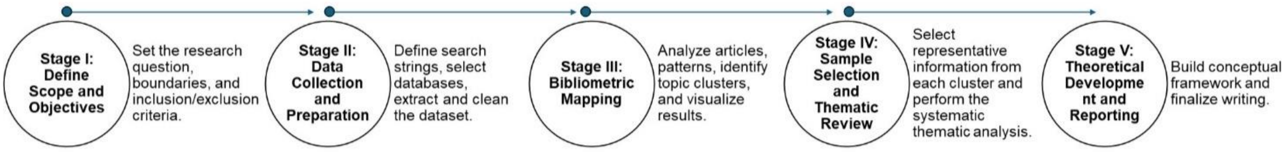

Figure 1. Five-stage structure for this review. Source: Own elaboration

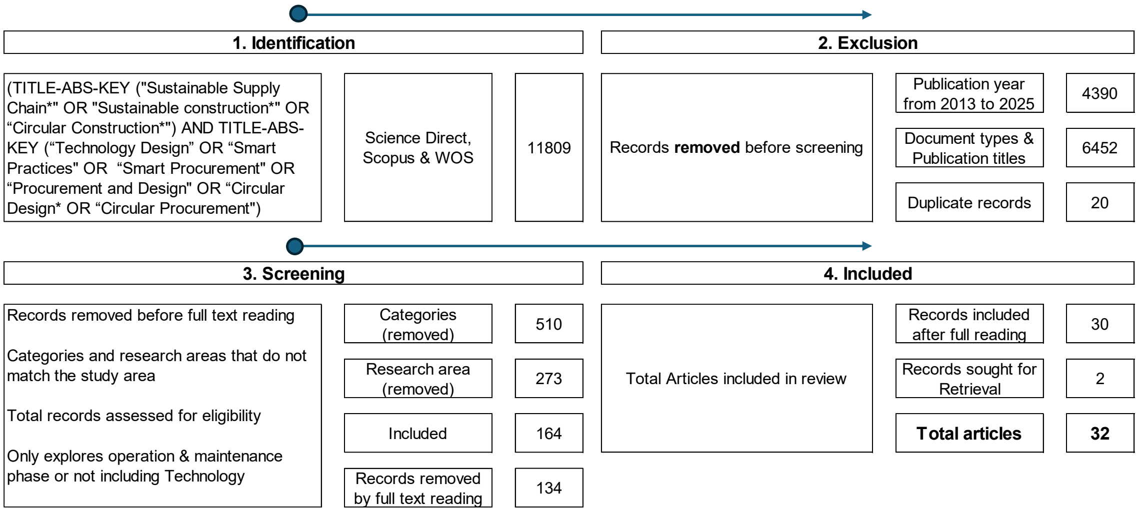

Figure 2. Flow diagram of study selection based on PRISMA 2020.

In Stage III, the PRISMA selection process, shown in Figure 2, guided title and abstract screening and full-text eligibility assessment (Moher D et al., 2009). A detailed eligibility review confirmed whether each article explicitly addressed smart procurement and/or smart design, resulting in 32 studies retained for in-depth analysis (Page et al., 2021).

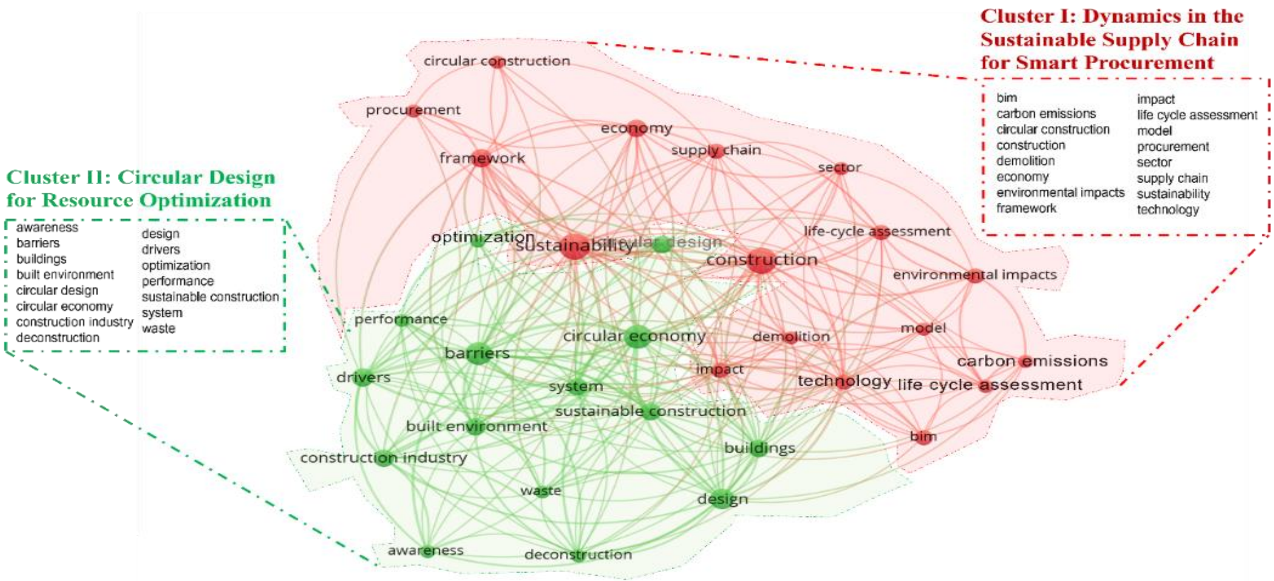

Figure 3. Trend clusters identification.

Stage IV applied bibliometric cluster analysis to the 32 selected articles using VOSviewer (van Eck & Waltman, 2010), with a minimum keyword occurrence threshold to map co-occurrence networks

(Figure 3) (van Eck & Waltman, 2014). Two principal clusters emerged—one focused on sustainable supply-chain dynamics and smart procurement, the other on circular design for resource optimization. Finally, Stage V synthesized insights from both clusters into an integrated conceptual framework that delineates how smart procurement and design practices interact as upstream levers of circularity.

3 Results

Table 1 presents a synthesis of the 32 research articles selected, categorized according to their primary thematic alignment with Cluster I Dynamics in the sustainable supply chain for smart procurement and/or Cluster II Circular design for resource optimization. Several articles span both clusters, suggesting growing interest in integrated approaches that link procurement decisions with design practices through digital tools.

Table 1. Classification of Selected Articles by Thematic Cluster, Keywords, and Citation Frequency

Authors – citation	Cluster I	Cluster II	Representative - Keyword	Total Citations[1]
(Abdulai et al., 2024)	x	x	built environment, waste management	17
(Ajayi et al., 2019)		x	building energy analysis, embodied emission	45
(Amarasinghe et al., 2024)	x	x	circular economy, construction waste management	6
(Atta et al., 2021)	x	x	material passport, building information modeling	58
(Bostancı et al., 2024)	x		construction supply chain, natural language processing	1
(Chan et al., 2017)	x	x	green building	135
Charef, Rabia; Lu, Weisheng	x	x	circular economy	55
(Lima et al., 2023)		x	circular economy, flexible architecture	15
(Figueiredo et al., 2024)		x	blockchain, digital twin	1
(Ghaffar et al., 2020)	x	x	circular construction, construction and demolition waste	293
(Guerra et al., 2021)	x	x	circular economy, construction industry	67
(Hao et al., 2020)		x	carbon emissions, prefabrication	186
(Honic et al., 2021)		x	material passports, circular economy	65
(Jayawardana et al., 2023)	x	x	environmental impacts, prefabricated construction	38
(Kar & Jha, 2021)	x		sustainable material management	11
(Karlsson et al., 2021)	x	x	supply chain, buildings	51
(Kumar & Zhang, 2024)	x	x	carbon emission reduction, project delivery methods	0
(Le et al., 2024)		x	circular bio based building materials	4
(Mhatre et al., 2023)	x	x	circular economy, built environment	34
(Mojumder & Singh, 2021)	x		green supply chain	53
(Motalebi et al., 2022)		x	decision making, building information modeling	52
(Nußholz et al., 2019)		x	circular business models, sustainable buildings	168
(Housh Sadat et al., 2024)		x	sustainable architecture integration, net zero energy	10
(Topraklı, 2024)	x	x	circular economy, building information modeling	0
(Wang & Pan, 2023)	x		embodied energy and emission, building sector	5
(Wong et al., 2015)		x	energy efficiency, carbon accounting	28
(Wuni, 2023)	x		circular construction, circular construction projects	23
(Yap et al., 2024)	x		green procurement	1
(Yevu et al., 2021)	x		digitalization, industry 4.0	74
(Yu et al., 2024)		x	environmental product declarations	0
(Zhan et al., 2024)	x	x	circular economy	0
(Zhang et al., 2024)	x	x	modular construction, supply chain	2

[1]Citations according to Web of Science core collection

3.1 Cluster I: Dynamics in the Sustainable SCs for Smart Procurement

Studies emphasize the need for procurement frameworks that incorporate environmental criteria such as embodied carbon limits, recycled content mandates, and supplier circularity performance metrics (Abdulai et al., 2024; Yap et al., 2024). For example, integrating carbon reduction criteria such as lifecycle-costing requirements and sustainability performance metrics directly into tender documents and contracts enables owners to require and reward circular practices from manufacturers and contractor (Kumar & Zhang, 2024). In addition, green procurement practices have been linked to an increased use of recycled materials and reduced carbon impacts in construction SCs (Wuni, 2023).

In this context, the development of procurement guidelines that prioritize circular materials fosters multi-stakeholder collaboration is considered a critical success factor to embed circularity in procurement decisions (Atta et al., 2021). Smart procurement emerges as a key enabler of sustainability in construction (Yap et al., 2024). These collaborations have supported the creation of shared platforms for data exchange such as material passports (Amarasinghe et al., 2024), and digital product logs, which link product origin, composition, and reuse potential (Yap et al., 2024).

3.2 Cluster II: Circular Design for Resource Optimization

Circular design practices aim to maximize product longevity, facilitate disassembly, and enable material recovery at end-of-life (Zhan et al., 2024). Design for disassembly is widely cited, promoting connections and assemblies that can be reversed without damage (Honic et al., 2021; Lima et al., 2023). Life-cycle assessment integrated in design supports CE in construction by quantifying embodied impacts of material choices (Karlsson et al., 2021). When applied early, life-cycle assessment helps designers compare material alternatives such as cross-laminated timber versus reinforced concrete on both environmental and recovery metrics (Motalebi et al., 2022). Digital tools like BIM further augment circular design by simulating assembly sequences, tracking material transforms, and enabling virtual disassembly (Yevu et al., 2021).

4 Conceptual Framework for Embedding Circularity

4.1 Gap Analysis and Conceptual Foundations

This review confirms that while smart procurement and circular design practices are well documented individually, their integration across SCs remains limited (Amarasinghe et al., 2024; Zhan et al., 2024). Clusters I and II map smart procurement and circular design practices, but embedding circularity in the construction SCs requires integrating them into a unified framework, and its success hinges on filling two core gaps: strategic alignment across actors and a shared data infrastructure. Bridging these gaps demands three enablers: policy and regulatory reform that codifies common CE objectives, restricting early-stage CE interventions (Kumar & Zhang, 2024; Guerra et al., 2021; Topraklı, 2024); technology infrastructure and tools to support real-time data sharing; and stakeholder collaboration and knowledge exchange (Wuni, 2023; Zhang et al., 2024)., which establish governance structures and feedback loops to keep owners, designers, contractors, and suppliers aligned.

The framework is organized horizontally to reflect the progression from strategic alignment to operational implementation and vertically by the digital tools that support decision-making at each stage. Strategic elements such as platforms for mapping extended supply networks and smart contracts enable early alignment around circularity objectives (Rathnayake et al., 2022; Yevu et al., 2021), while tools like blockchain (Figueiredo et al., 2024), and BIM (Atta et al., 2021; Motalebi et al., 2022) support the development of a robust data infrastructure. This infrastructure facilitates traceability, material evaluation, and supplier selection informed by life-cycle performance (Jayawardana et al., 2023; Motalebi et al., 2022).

This framework shares common ground with the tool-mapping structure proposed by Cambier et al. (2020) (Cambier et al., 2020), who catalogued digital design tools across project phases focused primarily on the technical availability of such tools. The proposed framework, in Figure 4, incorporates the tools and their role within an integrated governance system that includes strategic alignment and multi-actor coordination into a feedback loop. By combining smart procurement and circular design practices under a unified data and process infrastructure, this framework emphasizes the importance of early-stage interoperability, continuous learning, and decision-making mechanisms for addressing systemic barriers to embedding circularity in the construction SCs.

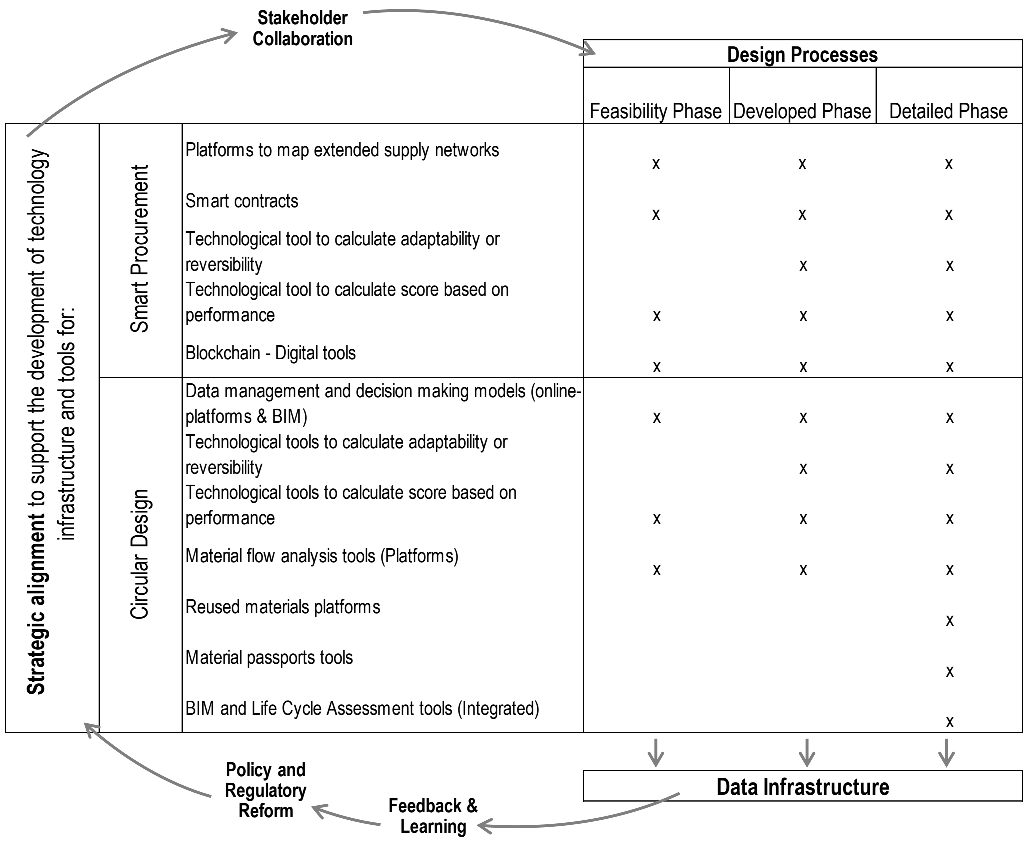

Figure 4. Framework for embedding circularity in the construction SCs supported by smart procurement and circular design practices

4.2 Policy and Regulatory Reform

Policy and regulatory frameworks play a critical role in enabling both smart procurement and circular design practices. Studies highlight that mandated procurement criteria such as embodied carbon limits, environmental product declarations, and supplier performance metrics can institutionalize circularity and incentivize life-cycle thinking in public and private tenders (Ajayi et al., 2019). Similarly, updating building codes to formally recognize strategies like modular design, design for disassembly, and LCA-guided material selection is essential for translating circular principles into technical practice (Lima et al., 2023; Honic et al., 2021). Yet, fragmented regulations and the lack of clear protocols for material reuse and product certification often hinder implementation (Sehnem et al., 2019). Thus, regulatory reform is foundational to scaling circular practices by providing legal clarity, standardizing expectations, and reducing the market uncertainty that currently discourages long-term investment in circular construction models.

4.3 Technology Infrastructure and Tools

Digital technologies such as BIM and material passports are essential enablers for embedding circularity across design and procurement stages. BIM facilitates advanced simulations that support modular design, disassembly planning, and end-of-life material recovery strategies, especially when integrated with life-cycle assessment to assess environmental performance in real time (Lima et al., 2023; Motalebi et al., 2022). Material passports, in turn, provide structured data on durability, reuse, and recyclability, helping align design intent with procurement decisions (Honic et al., 2021). These tools reduce data fragmentation and promote information consistency, which is vital for addressing the lack of visibility across extended SCs a known barrier to circularity. The combination of interoperable digital systems and standardized material data enables multi-stakeholder coordination and supports circular objectives throughout the project lifecycle (Atta et al., 2021).

4.4 Stakeholder Collaboration and Knowledge Exchange

Effective stakeholder collaboration in circular construction requires visibility and coordination beyond first-tier suppliers, as many environmental and social risks originate deeper within the supply network (Choi et al., 2021). Procurement templates and standardized design protocols can align circular objectives across actors, but their success depends on transparent, multi-tier engagement and access to reliable material and supplier data. Digital tools such as material passports facilitate traceability and reuse planning (Honic et al., 2021), while BIM can support environmental performance tracking and coordination across project teams (Atta et al., 2021). These infrastructures help reduce information asymmetries and enable clients, designers, and contractors to co-develop procurement and design practices that embed circularity in the construction SCs (Díaz Caselles & Guevara, 2024).

5 Conclusions

This systematic review confirms that embedding circularity in the construction SCs requires early-stage interventions that go beyond isolated practices in procurement or design. Smart procurement frameworks when supported by performance criteria, digital data tools, and multi-tier supplier visibility, enable more transparent and sustainable material flows. Concurrently, circular design practices such as design for disassembly, modularity, and BIM integrated life-cycle assessment offer concrete mechanisms to reduce embodied impacts and facilitate material recovery. However, their potential remains constrained by institutional fragmentation, short-term cost biases, and the absence of standardized protocols linking procurement decisions with long-term design outcomes.

To address these systemic barriers, this study proposes a conceptual framework that integrates strategic alignment, data infrastructure, and feedback loops across smart procurement and circular design processes. The implementation of smart procurement and circular design practices must be supported by enabling conditions at the system level, including regulatory alignment, digital infrastructure, and multi-actor collaboration. Without such support, isolated project-level practices may struggle to achieve lasting impact.

Policy reforms mandating circular criteria in procurement and updated building codes are critical for institutionalizing these practices. Likewise, digital enablers such as material passports and BIM platforms offer the interoperability and traceability needed for extended SCs management. Finally, stakeholder collaboration mechanisms grounded in transparent, multi-tier governance are essential to align incentives and operationalize circularity across project actors. By linking upstream decisions with downstream impacts, this integrated approach advances the implementation of CE principles in construction and sets the foundation for future empirical and practice-oriented research.

Data Availability Statement

Data will be made available on request

Conflicts of Interest

The authors declare no conflict of interest.

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