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REVIEW ARTICLE

Integrating Sustainable Material Procurement in Construction Waste Management: A Systematic Review With Narrative Synthesis for the Libyan Construction Sector

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ABSTRACT

Integrating sustainable material procurement with construction waste management is essential to reduce construction and demolition waste in Libya, where current practices remain largely reactive and disposal-oriented. This narrative review aims to develop a conceptual framework linking procurement decisions to waste-generation pathways in Libyan construction projects, clarifying how proactive, sustainability-driven purchasing can serve as a primary driver of waste prevention. Using a PRISMA-guided systematic search of Web of Science, Scopus, and IEEE Xplore for 2001–2026, and a bibliometric analysis via VOSviewer, 956 high-quality studies were synthesized to map global knowledge and to expose the paucity of integrated SMP–CWM studies in developing economies, particularly Libya. The review identifies that practices such as Just-in-Time delivery, sustainable supplier selection, green procurement criteria, and digital technologies (e.g., BIM-enabled material estimation, IoT tracking, and AI-based forecasting) significantly improve material efficiency, reduce over-ordering, and lower landfill dependency while supporting circular economy outcomes. It also reveals persistent barriers in Libya, including weak regulatory enforcement, limited circular economy, low adoption of lean procurement, high implementation costs, and low stakeholder awareness, all of which constrain the mainstreaming of sustainable procurement. This review provides practitioners and policymakers with a structured pathway that connects procurement strategies, green building practices, and technological integration to measurable waste management indicators, including waste minimization, recycling rates, and cost savings. In practice, the study recommends targeted policy reforms, financial incentives, and capacity-building programs to embed sustainable procurement requirements across public and private projects, thereby enabling Libyan construction firms to optimize resource utilization, enhance environmental performance, and align with national sustainability and circular-economy ambitions.

Keywords: Sustainable material procurement, Construction waste management, Green procurement, Circular economy, Environmental sustainability

1. Introduction

The construction market is vital for economic growth, as it helps develop infrastructure, provides employment opportunities, and contributes to urban expansion. On the one hand, it is a primary driver of environmental destruction, resource consumption, and waste. Construction and demolition waste (C&DW) is one of the largest waste streams worldwide, accounting for at least 30% of total solid

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waste and reaching 30–40% in many regions [1, 2]. It has negative environmental impacts, including land degradation, air and water pollution, and greenhouse gas (GHG) emissions [3]. This is compounded in many developing countries, including Libya, by unsystematic waste management policies and weak enforcement of regulations, leading to inefficient disposal pathways such as landfilling and illegal dumping. A departure from traditional waste management paradigms and approaches is crucial to tackling these challenges, and sustainable material sourcing (SMP) is one such proactive strategy that can play a significant role in source reduction [4]. Sustainable procurement of construction materials requires sourcing materials that prevent environmental harm (from production, transportation, application, and end of life). It has been demonstrated that procurement practices, such as over-ordering, the use of non-recyclable materials, and inadequate coordination between procurement and construction teams, can lead to material waste at the construction site [5]. In addition, if construction management makes an ineffective choice in how to purchase building materials, this will result in unnecessary stockpiling, unsuitable accommodation, and premature decay, thereby increasing waste [6]. However, the adoption of sustainable practices, such as green procurement and life-cycle assessment, and the use of new tools to support efficient procurement and prevent waste were not common in Libya. Therefore, the construction industry in Libya prioritizes cost efficiency over sustainability.

The integration of procurement methods with waste management initiatives has been successful globally in mitigating construction waste [6]. Abdulsalam et al. (2024) note that in countries adopting green supply chain management, lean construction principles, and electronic procurement systems, progress in minimizing waste and increasing material efficiency is unquestionable. Examples of such solutions include Building Information Modelling (BIM), which is widely used to enhance material costing, procurement scheduling, and on-site waste tracking, thereby minimizing material waste [5]. Governments in developed countries have also introduced stringent environmental policies requiring the construction industry to use sustainable and recyclable materials [7]. However, this cannot lead to sustainable procurement practices in Libya, where there are no policies in place to achieve them, combined with limited access to usable resources and an industry reluctant to change [8]. Such issues require systematic solutions that develop sustainable procurement plans and align with waste management efforts to enhance environmental and economic sustainability. The research problem this study addresses is the limited and ineffective methods used to handle construction waste in Libya. Many of these studies have measured waste generation, explored disposal methods, and examined recycling opportunities, but sustainable procurement has not been investigated as a potential waste-prevention strategy [4]. The techniques for managing construction waste in Libya have historically focused on post-construction waste disposal rather than on procurement-driven waste optimization strategies. In addition, limited empirical evidence exists on critical challenges and enablers of sustainable procurement implementation in the Libyan construction industry, which influence procurement decisions and waste generation [9]. The objective of this study is to address this gap by developing a conceptual framework for sustainable material procurement in the management of construction waste. This framework offers a step-by-step approach to enhancing sustainability, mitigating environmental impact, and improving procurement efficiency in the Libyan construction sector.

The research aims to answer the following question: What are the main drivers of sustainable material procurement in the construction industry? How does material selection affect the amount of construction waste produced? What are the factors that make it challenging to adopt sustainable procurement practices in managing construction waste in Libya? How can we better connect the dots between waste reduction and procurement decisions? Addressing these questions would enhance a holistic understanding of the link between purchasing structures and waste and clarify how Sustainable Procurement can be applied as a proactive driver of waste prevention [4]. This research is essential because it enhances the theoretical understanding of the interface between procurement and waste management, while also providing practical solutions to construction firms, policymakers, and regulators in Libya. The research will assist in developing a conceptual framework that integrates procurement with waste management strategies to optimise resource utilisation, reduce construction waste, and enhance sustainability outcomes. The study is also relevant to international circular economy principles, as it supports material recycling and reuse, as well as sustainable sourcing practices, which align with Libya's aspirations to become an environmentally sustainable country [8].

This research will also inform policy development by providing evidence-based recommendations to support sustainable procurement policies in construction projects. The remainder of this paper is structured as follows: The next section reviews the existing literature on construction waste mitigation strategies, sustainable material procurement, and their integration at both the global and local levels in Libya. This section of the article will describe the research design, data collection methods, and the methodology used to develop the framework. Thereafter, the theoretical structure conceived for the design will be elaborated, along with its essential features and the methods for its adoption. The feasibility and potential impact of the framework will be discussed and contrasted with previous models, followed by policy recommendations in the discussion and implications section. Ultimately, the conclusion will summarize the most significant findings and outline potential future directions for more targeted research and practical applications. With this structure, the paper will outline sustainable material procurement and its role in minimizing construction waste in Libya in a detailed and systematic manner.

Despite extensive international research on construction waste management and sustainable procurement, most studies examine these themes separately and are rooted in developed economies, where regulatory systems, technologies, and market incentives differ substantially from those in Libya. Existing Libyan studies primarily emphasize post-construction disposal, landfilling, and basic recycling options, with little focus on procurement-driven waste prevention or on integrating circular economy and lean procurement principles into waste management. This study makes three main contributions. First, it offers the first narrative review that explicitly integrates sustainable material procurement and construction waste management for the Libyan construction sector, drawing on a PRISMA-guided synthesis to map the global knowledge base and situate Libya's position within it. Second, it identifies Libyan-specific gaps related to weak regulatory support, limited adoption of circular-economy and lean procurement practices, scarce empirical data on procurement behaviour, and fragmented stakeholder collaboration, thereby clarifying why global models cannot be transferred directly. Third, it proposes a Libyan-tailored conceptual framework that links procurement strategies, green building practices, and digital technologies to construction waste indicators, providing policymakers and practitioners with a structured pathway for transitioning from reactive disposal practices to proactive, sustainability-oriented procurement and waste prevention

2. Research selection method

The systematic review process, as illustrated in the PRISMA diagram (Fig. 1), follows a structured and rigorous approach comprising three main stages: preparation, database search, and results consolidation. The process begins with the preparation phase, which involves defining a clear and focused research question on how sustainable material procurement can be integrated with construction waste management, particularly in the Libyan context. This question serves as the foundation for identifying relevant keywords and subject areas to guide the search strategy and for specifying inclusion and exclusion criteria that ensure consistency and transparency in selecting studies (e.g., publication year, study type, language, sectoral relevance, and conceptual focus on procurement–waste linkages).

In the database search phase, three major databases, Web of Science (WOS), Scopus, and IEEE Xplore—were selected because they provide broad coverage of peer-reviewed journals and high-quality conference proceedings in construction, sustainability, and management (WOS and Scopus) as well as technologically oriented work on BIM, IoT, AI, and digital procurement systems (IEEE Xplore), which are central to the proposed framework. The databases were queried using the combined search string "(TITLE-ABS-KEY(material AND procurement) OR TITLE-ABS-KEY(construction AND materials AND waste AND management) AND TITLE-ABS-KEY(circular AND economy AND in AND construction) OR TITLE-ABS-KEY(environmental AND impact AND of AND procurement)) AND (LIMIT-TO(LANGUAGE, 'English'))" for the period 2001–2026. This strategy yielded 523 records from WOS, 612 from Scopus, and 210 from IEEE Xplore, and all metadata were exported for screening and analysis.

Inclusion criteria required that records: (i) were peer-reviewed journal articles, conference papers, or scholarly book chapters; (ii) were written in English; (iii) fell within the 2001–2026 publication window; and (iv) addressed at least one of the core domains of the review—sustainable material procurement, construction and demolition waste management, circular economy in construction, or the environmental impacts of procurement—with clear relevance to the research questions. Studies that were editorials, notes, short communications, retractions, non-scholarly reports, not focused on the construction sector, or lacking methodological transparency were excluded. This stage aims to ensure comprehensive yet focused coverage of the available literature and to minimise the risk of including low-quality or marginally relevant studies.

In the results consolidation phase, all records from the three databases were combined into a single dataset. Duplicates were removed, reducing the total from 1,345 to 1,203 unique records. The remaining studies underwent title and abstract screening to

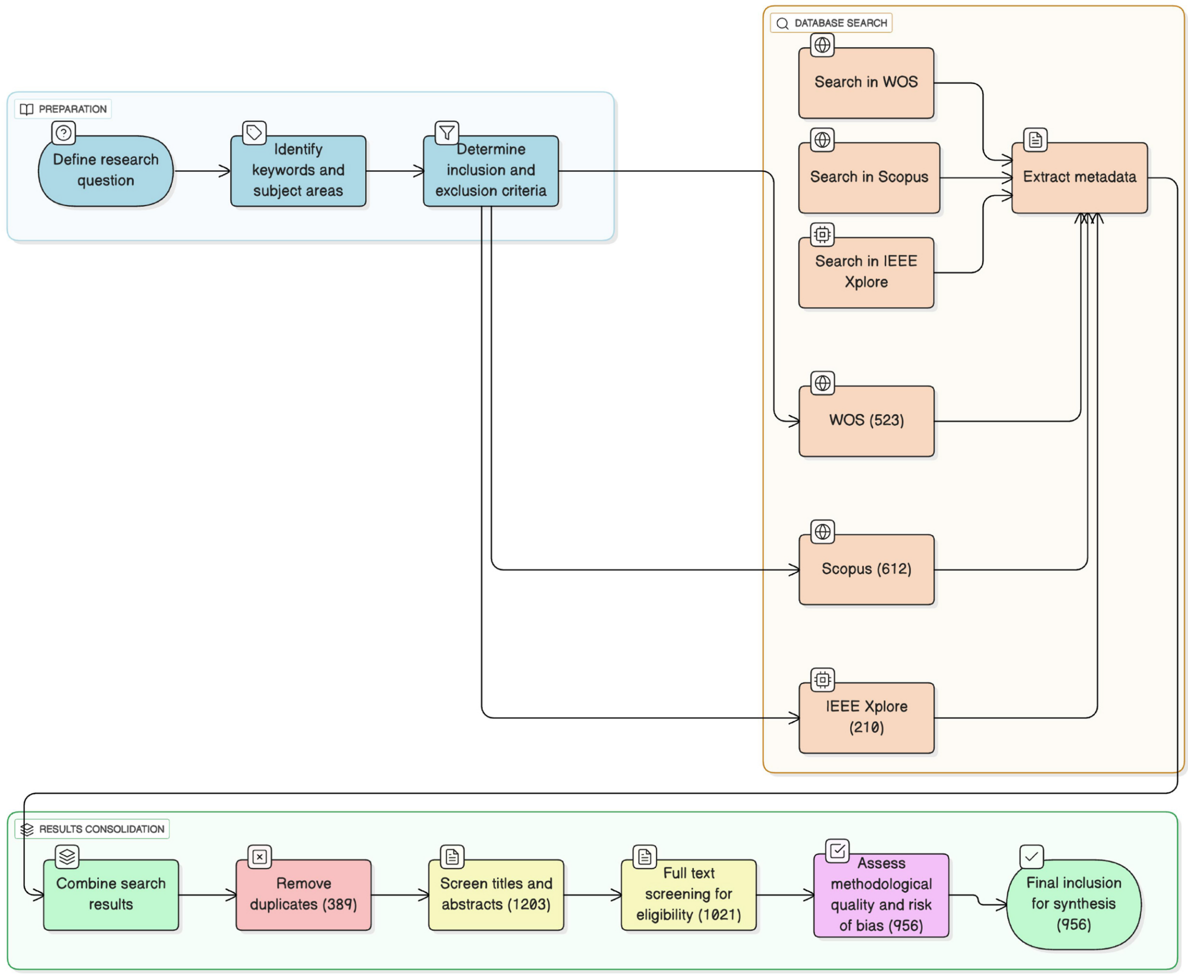

Fig. 1. Methodology for identifying, screening, and integrating pertinent research.

exclude those outside the scope. Full-text screening was then conducted for 1,021 eligible records to verify compliance with the inclusion criteria. At this stage, each study was further assessed for basic methodological quality (clarity of research design, data sources, and analysis) and potential risk of bias. A total of 956 studies met all requirements and were included in the final qualitative and bibliometric synthesis. This step-by-step process prioritises quality over mere volume and enhances the validity and reliability of the review, while the PRISMA framework supports reproducibility by making each stage of study selection transparent.

Bibliometric data were collected and augmented using VOSviewer software for knowledge mapping. These maps illustrate the interrelationships among contemporary publications, based on journal-institution affiliations. The initial phase involves conducting a search utilizing pertinent keywords, specified algorithms, and relevant concerns where algorithms are predominantly employed. Fig. 2 illustrates the standard representation of esteemed papers concerning the procurement and management of waste in construction. The bibliometric analysis maps the intellectual and geographical landscape of sustainable procurement and construction waste management research and demonstrates the paucity of integrated SMP–CWM studies in developing economies, particularly Libya. This contextualisation helps to justify the focus of the conceptual framework on Libyan-specific regulatory, institutional, and technological gaps, but the core framework development does not depend on the detailed bibliometric metrics.

Using VOSviewer, Fig. 3 shows a map of a network of co-authors by nation. The illustration shows how nations collaborate based on research papers they have written together. The size of each node indicates the number of articles linked to that nation. Each node stands for a country. Bigger nodes suggest that more research is being conducted and that more people are collaborating on international projects. The United Kingdom is the most critical and influential node in the network. This means that it is

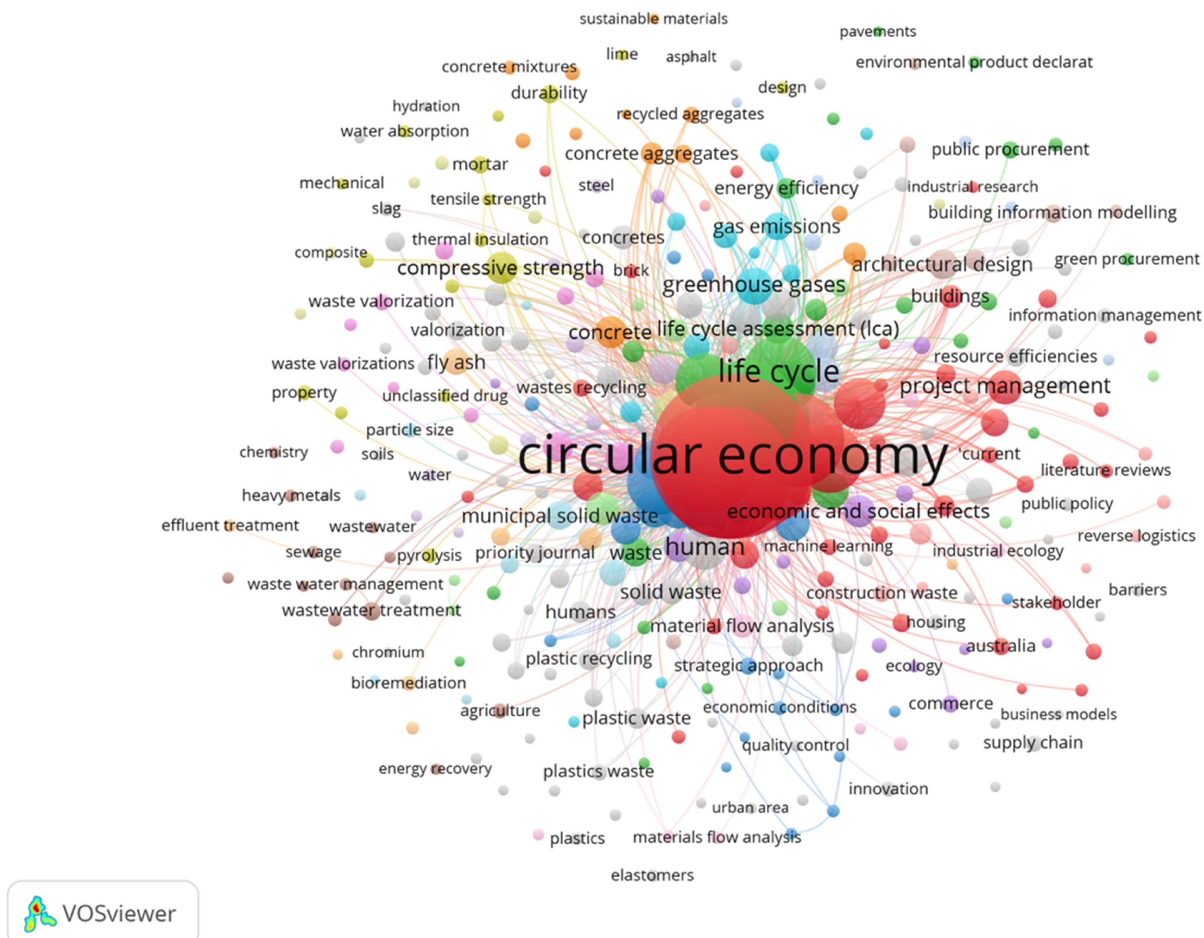

Fig. 2. Visual representation of the term distribution of keywords.

a crucial aspect of scientific collaboration worldwide. India, the United States, Brazil, Malaysia, and Turkey are all critical contributors. They have substantial scientific relations with the UK, both bilaterally and multilaterally. The colorful groups on the map represent countries that often collaborate. These groups demonstrate how researchers from the same area or with similar interests collaborate. This might be because they live close to each other, have a history together, or share an interest in the same study topics. For instance, Germany, France, and the Netherlands are all part of a group that demonstrates their close collaboration. Countries in Asia and the Middle East also form their groups.

The bar chart in Fig. 4 portrays the distribution of publication formats that have investigated the circular-economy procurement topic, after pruning away categories with only scattered contributions. The figure depicts a robust research ecosystem. Peer-reviewed journals anchor the discourse, conferences supply early-stage innovation, reviews curate collective wisdom, and book chapters extend reach across disciplines. The long-tail categories that were removed—editorials, notes, short surveys, retractions—are comparatively negligible and do little to influence overall trends, so their exclusion sharpens focus on the substantive core of the literature.

The chart in Fig. 5 visualizes an evolving, globally dispersed research landscape in which a handful of countries provide a critical mass, but momentum is spreading outward, promising richer cross-regional insights into sustainable procurement and construction material management. The bar chart displays the twenty most-productive countries (in terms of Scopus-indexed publications) on the topic you queried. The United States and the United Kingdom dominate the list, with each surpassing 100 publications. They act as global hubs for research on the circular economy and construction procurement, likely reflecting both their large research communities and strong policy interest in waste reduction. With a close chasing pack, India, Italy, Australia, and China form a tight second tier. Their counts differ by only a few dozen papers, suggesting a competitive yet collaborative middle group in which emerging

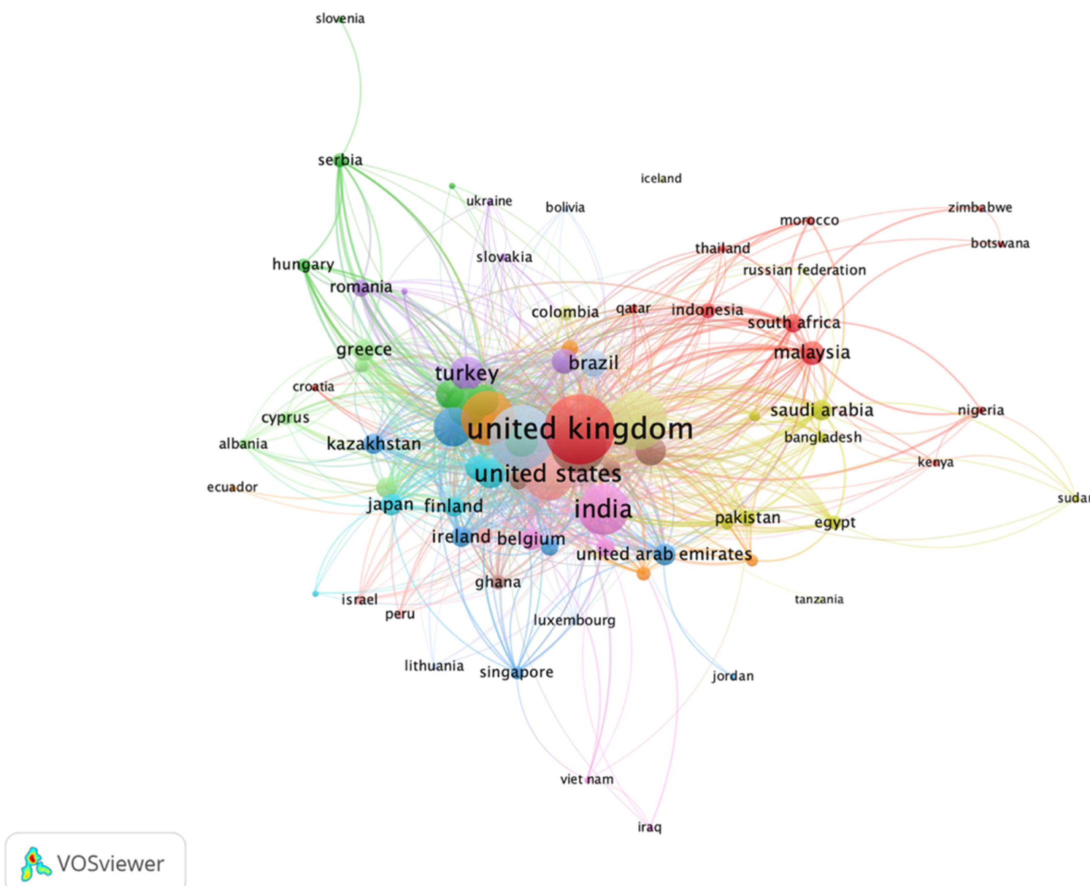

Fig. 3. Graphical depiction of the distribution of publications according to their country of origin.

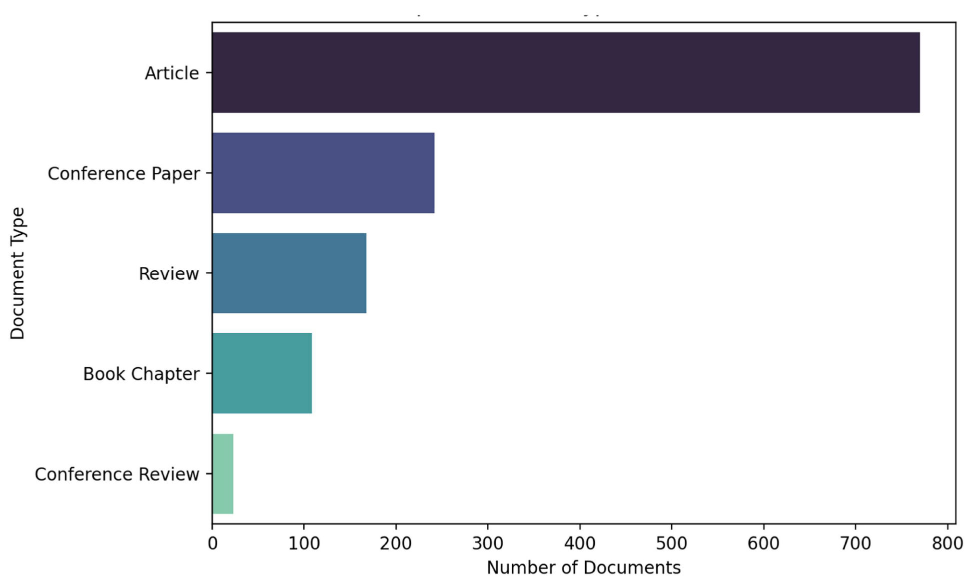

Fig. 4. The distribution of publication types.

economies (India, China) coexist with established research nations (Italy, Australia).

On the other hand, Europe is heavily represented (the UK, Italy, Germany, Spain, France, the Netherlands, and Sweden), yet Asia–Pacific and North America also appear—evidence that the field is no longer Eurocentric. After the top six, publication counts drop quickly. This "long-tail" indicates many

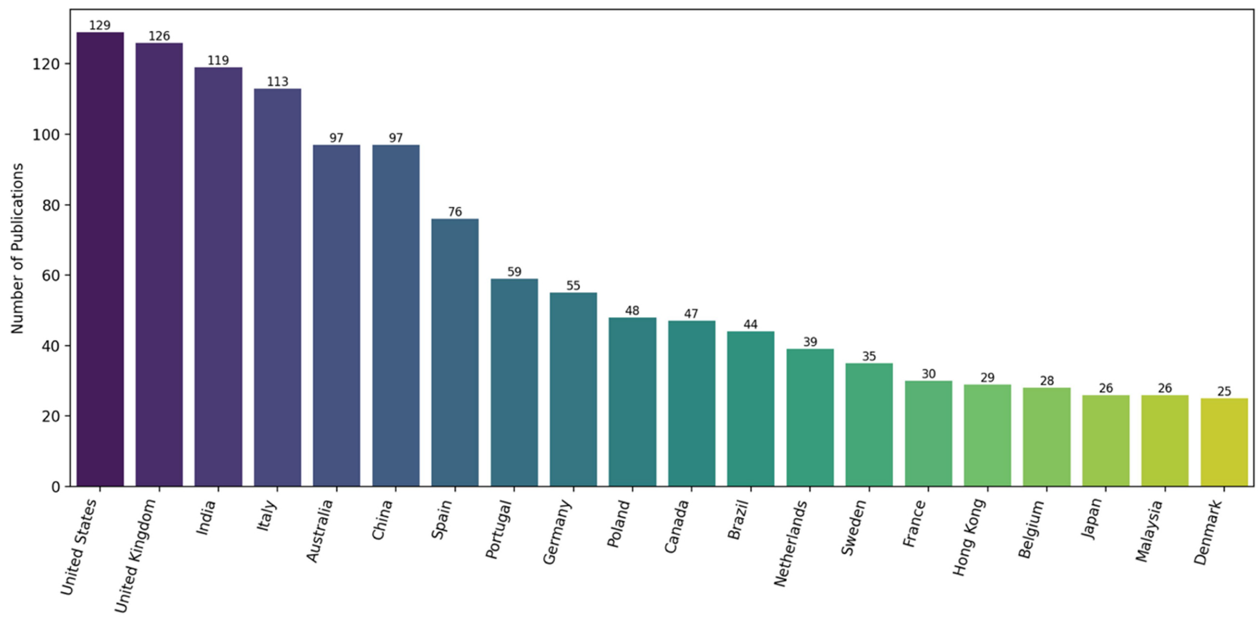

Fig. 5. The publication frequency per country.

countries contribute occasional studies, enriching the literature's diversity but relying on a smaller core for volume.

Interpretation. The figure implies that policy discourse and funding priorities drive publication output. Nations with robust circular-economy legislation (EU members, UK) or large construction sectors (US, China, India) publish the most. Meanwhile, countries lower on the list may be newer entrants or face resource constraints, signalling opportunities for capacity-building and international collaboration.

3. Theoretical foundations

The synergy of sustainable material procurement (SMP) in construction waste management (CWM) can be understood through various theoretical paradigms that reflect resource efficiency, waste minimization, and sustainability. Thus, utilizing theories such as Lean Construction, Circular Economy (CE), Triple Bottom Line (TBL), Institutional Theory, and Stakeholder Theory to facilitate the systematic integration of procurement and waste management strategies is a key focus of this research. These theories underpin a conceptual framework for sustainable construction in Libya.

3.1. Lean construction theory

Lean Construction Theory is influenced by Toyota-based lean manufacturing principles, which aim to minimize waste, increase efficiency, and maximize value for project stakeholders [10]. In construction (Fig. 6), lean principles focus on eliminating specific non-value-adding activities that contribute to construction waste, such as over-ordering of materials, excessive inventory storage, and inefficient logistics planning [4]. Reducing waste (not just cost) in the construction industry is the primary aim of lean construction, enabling the flow of work components and construction materials with minimal waste and maximum efficiency [5]. Just-in-Time (JIT) procurement is a crucial strategy in lean construction, where materials are ordered and delivered on-site as needed, thereby reducing the risk of material waste, damage, or theft. Prefabrication is another lean construction practice, as it produces building components off-site and assembles them on-site, resulting in significantly lower material consumption and reduced on-site construction lag. By adopting lean procurement principles, construction firms can improve material efficiency, reduce procurement costs, and minimize environmental impacts. Challenges such as limited technological infrastructure, a lack of trained professionals, and resistance to change in procurement and project management practices have been identified as key barriers to the wider adoption of lean and other modern construction approaches in Libya. Studies on Libyan construction projects highlight constraints, including limited access to advanced digital tools such as BIM, limited awareness and training in lean concepts, and broader institutional and regulatory obstacles, all of which hinder the implementation of lean-based procurement and waste-reduction strategies [11].

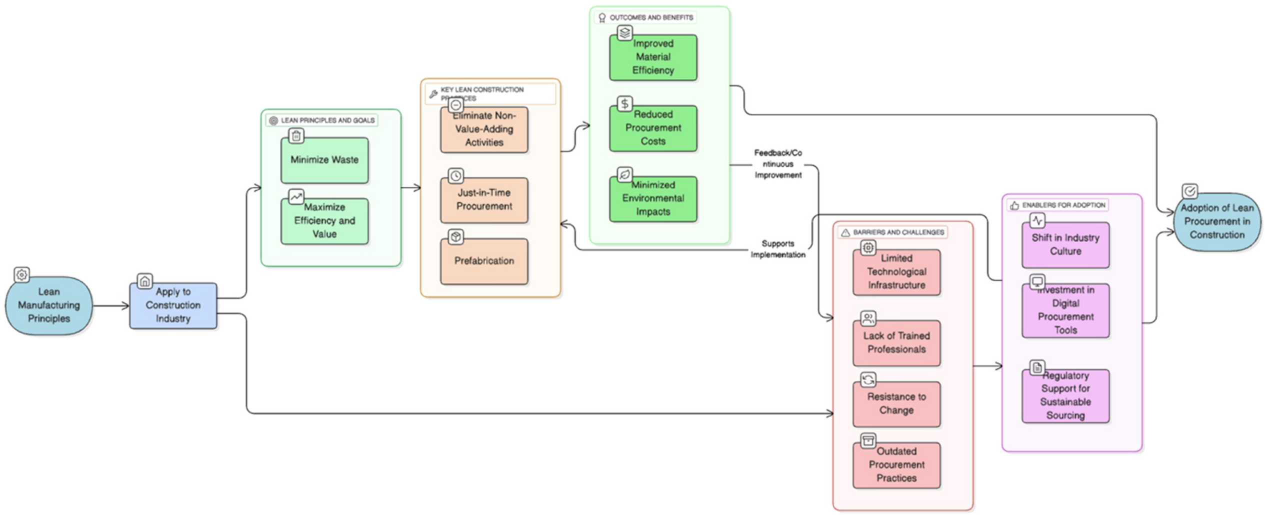

Fig. 6. Lean manufacturing principles and adoption in procurement and construction.

3.2. Circular economy principles

The Circular Economy (CE) is another theoretical concept that supports integrating sustainable procurement into construction waste management. In contrast to the linear economy's "take-make-dispose" approach, the CE offers an alternative model that promotes the efficient use of resources by reusing materials and valorising waste. CE principles emphasize the concept of a closed loop within construction, as illustrated in Fig. 7, which maximizes the lifespan of materials by recycling, repurposing, and reusing them [6]. This approach involves selecting sustainable, recyclable, and reusable building materials during procurement, based on the principles of the circular economy [5]. In many developed countries, legislation has been enacted to mandate the use of reclaimed resources and other materials in projects, thereby reducing the need for primary materials and minimizing waste [7].

Additionally, to encourage waste minimization and circularity in the construction industry, deconstruction methods — which involve systematically dismantling buildings to recover reusable materials — have gained widespread adoption. Nevertheless, the implementation of a circular economy in Libya's procurement framework is limited due to the absence of a government policy for material reuse, poorly developed recycling infrastructure, and a lower level of awareness among construction stakeholders [8]. Most construction waste ends up in landfills or at open dumping sites, where it cannot be sorted for recovery or reintegration into new structures. One of the main reasons is that the procurement system provides little incentive for contractors and suppliers to switch from primary to recycled materials, with the emphasis being on the lowest price rather than the best life-cycle assessment. Removing these barriers requires reforming policies, investing in and commercializing recycling technologies, and implementing education programs that instill sustainable procurement practices.

3.3. Triple bottom line (TBL) approach

A key element of the TBL framework is its ability to help individuals consider economic, environmental, and social performance when making decisions. TBL is a model that can help guide building within the presence of real limits on resource use [4]. Economic sustainability in procurement refers to the cost-effective, financially viable implementation of sustainable procurement practices, ensuring that these practices do not impose undue costs on construction firms [9]. Environmental sustainability focuses on waste prevention and reduction, minimizing the carbon footprint, and utilizing environmentally friendly materials [3], as visualized in Fig. 8. While [12] also states that social sustainability relies on fair labour practices, stakeholder engagement, and community well-being in their procurement decisions. The application of TBL to construction waste management enables decision-makers to optimize profitability within the bounds of sustainability, ensuring that waste minimization and material efficiency are incorporated into procurement policies [8]. Numerous governments promote procurement policies based on TBL, providing tax incentives to organizations that utilize sustainable materials and embed circular economy (CE) concepts [13]. However, several challenges exist to the practical implementation of TBL in Libya. Contractors' economic priorities often

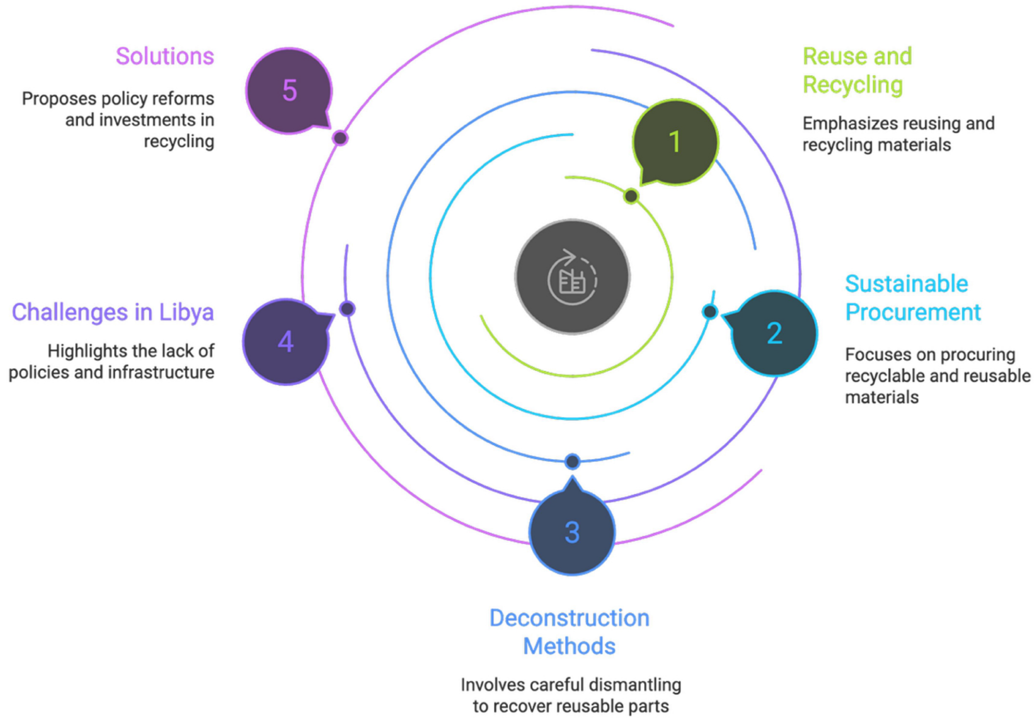

Fig. 7. The theoretical concept of the circular economy.

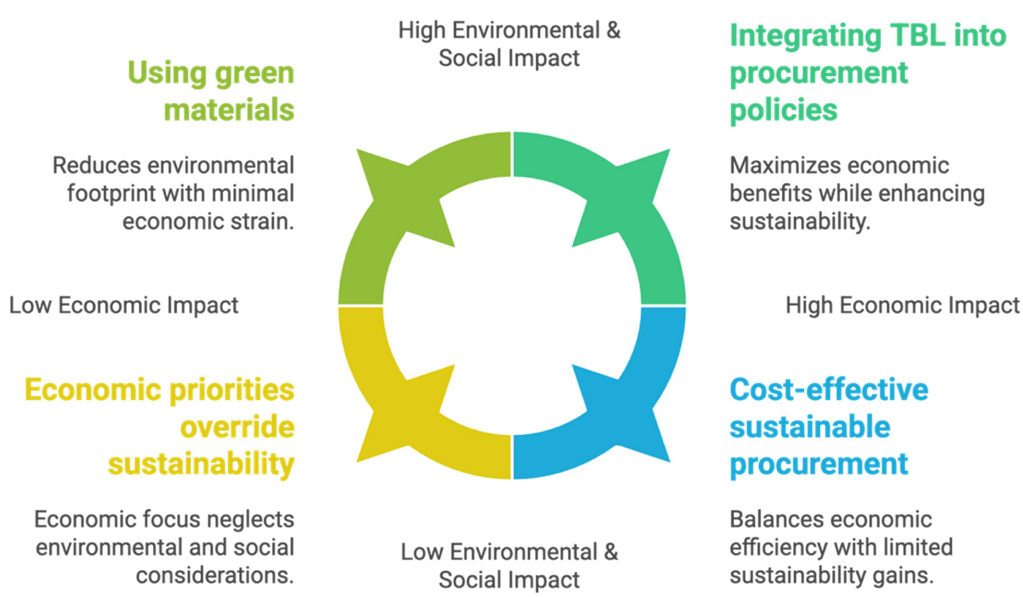

Fig. 8. The prioritizing of sustainability in the construction procurement.

take precedence over the environmental and social aspects of sustainable procurement, making it challenging to implement. Additionally, construction firms are facing less regulatory pressure to adopt green procurement strategies, which also restricts their acceptance. Such integration of TBL principles into Libyan procurement policies would help align economic incentives with environmental and social responsibility, thereby contributing to the development of a more sustainable construction industry.

3.4. Institutional theory

In particular, Institutional Theory has been widely used to explain how compliance with regulatory frameworks, industry norms, and organizational practices influences the adoption of sustainability initiatives [9]. Sustainable procurement is common in many developed nations, as stringent incentives, environmental laws, and penalties have compelled businesses to adopt sustainable procurement practices [6]. Nevertheless, in Libya, the continued adherence to conventional procurement can be attributed to institutional obstacles (weak government enforcement, the lack of sustainability policies, and limited awareness among construction enterprises). As described by Institutional Theory, governments are key actors that shape industry behavior through policies and practices of green procurement and construction waste management [12]. This is due to the higher rate of circular economy and lean procurement practices in countries with strict sustainability regulations [8]. Thus, it explains the significance of regulatory frameworks, financial incentives, and public awareness in improving sustainable procurement in Libya.

3.5. Stakeholder theory

Ajayi et al. emphasize the cooperation of multiple actors in construction waste management and procurement [4], a theme that Stakeholder Theory can support. A single actor does not make sustainable procurement choices; they involve multiple actors, including government agencies, contractors, material suppliers, clients, and environmental groups [6]. Sustainable procurement would not be possible without the involvement of these stakeholders, who play a critical role in sourcing green materials and reducing waste [12]. For example, in Libya, inadequate coordination among stakeholders retarded the adoption of sustainable procurement. Suppliers have no incentive to provide green materials, and contractors will always opt for short-term savings over long-term solutions. Government regulations, financial incentives, and industry-wide sustainability standards are necessary to prepare stakeholders to collaborate effectively [9]. This dynamic is further illustrated in Table 1, which highlights the critical role of collaborative engagement in sustainable procurement and waste management, particularly in the Libyan context.

4. Gap in the literature

While a sufficient body of knowledge has been developed exploring the concepts of construction waste management (CWM) and sustainable material procurement (SMP) separately, their integration into a complementary approach has not been adequately developed, especially in the context of developing countries like Libya. Most past studies have mainly concentrated on waste disposal and recycling strategies, while less attention has been given to proactive procurement-based strategic waste reduction [4, 8]. The following sections outline the main shortcomings in the literature and the contribution of a conceptual framework that integrates sustainable procurement into construction waste management.

4.1. Limited research on the link between procurement and waste generation

It is worth noting that significant research has investigated the causes and implications of construction waste; however, most studies have focused on post-construction waste management options, such as reuse, recycling, sorting, and landfilling [8, 13]. A growing body of work has begun to examine how procurement strategies influence construction waste generation, and how waste-efficient materials procurement and logistics measures can minimise waste. However, these contributions are largely situated in developed-country contexts and tend to focus on operational strategies at the project level rather than on developing an integrated, procurement-centred waste management framework calibrated to Libya's regulatory, institutional, and infrastructural conditions. Effective procurement is a significant determinant of material efficiency, and inappropriate procurement practices, including overestimation, poor material selection, and inadequate coordination with suppliers, are also likely to generate excessive waste [5]. Research conducted in developed countries has shown that sustainable procurement can significantly reduce waste in construction; however, knowledge of how to apply it in Libya, where procurement effectiveness and efficiency still pose significant challenges, is limited [11].

4.2. Lack of integration between sustainable procurement and waste management frameworks

Existing waste management frameworks are primarily focused on traditional methods of waste minimization, such as source sorting, material reuse, and waste treatment technologies [25]. However, sustainable procurement is not adequately embedded in any of these frameworks as a proactive solution for waste reduction. Conversely, in developed economies, green procurement policies are increasingly incorporated into waste management plans, ensuring that environmentally friendly, recyclable, and resource-efficient construction materials are selected to reduce waste generation [26]. However,

Table 1. Summary of key studies on sustainable procurement challenges and insights.

Reference	Challenges Identified	Methodology	Key Findings/Insights
[14]	– Weak organizational support – Uncertainty in recycled product quality	Mixed methods (49 sources)	– Clear governance and transparency are enablers – Proposed model for adoption in construction
[15]	– Limited frameworks – CSR impact unclear	Scientometric and visual analysis	– Public procurement varies globally – New frameworks needed for CSR integration
[16]	– No MD sustainability framework – Post-COVID resilience ignored	UN principles analysis and impact evaluation	– Future use of MDs matters – Framework links MD cost-benefit for health outcomes
[17]	– Neglected private sector – PMO role underexplored	Literature review and professional survey	– 17 procurement requirements identified – PMOs support collaboration and sustainability
[16]	– Gaps in developing nations' MD procurement – Lacks empirical BCEL role data	Local condition and market analysis	– BCEL critical for assessing local sustainability – Framework supports MD sustainability in low-resource areas
[18]	– Low consumer awareness – Green procurement impact unknown	Content analysis and face-to-face surveys	– Awareness highest in packaging – Green food procurement lowest
[19]	– Weak links in West Africa – Corruption, leaks in public funds	Literature review	– E-tax and procurement promote development – Emphasis on inclusion and anti-corruption
[20]	– No clear outcomes – Lacks case studies	Content analysis (sustainable food procurement)	– Public food procurement supports local and organic – Calls for better measurement tools
[21]	– One-case application only – Needs more refined tools	Framework and action research	– Risk trade-offs mapped – Shows complex sustainability cost-benefit links
[22]	– Regional imbalance – Misunderstanding of knowledge-use link	Survey (30 respondents) and SEM-PLS	– Procurement success influenced by drivers – Knowledge negatively correlated with implementation
[23]	– Procurement 4.0 integration lacking	SEM-PLS and business simulation	– Procurement 4.0 boosts efficiency – Process optimization supports sustainability
[4]	– Low waste supplier commitment – Weak delivery strategies	Supplier-based criteria analysis	– Waste-efficient procurement depends on packaging, JIT, BoQ control
[24]	– EMS maturity effect unclear – Weak public authority support	Statistical analysis (Italy)	– GPP success tied to awareness, not size-EMS maturity crucial over certification

there is no systematic foundation for purchasing activities in Libya that follow a circular material flow with minimal waste, which implies that there will be insufficient linkage between environmental-related purchasing and direct waste reduction functionality, as well as inefficient material usage and additional negative environmental impact [27]. Moreover, visualizing procurement strategies can provide an efficient approach to establishing a link between procurement and waste quantity; therefore, a clear gap in the literature exists for a framework to associate procurement with construction waste management.

4.3. Limited adoption of circular economy and lean procurement in Libya

Although it is not immediately apparent in waste management, the circular economy principle could still be a significant part of an environmentally sensitive procurement strategy [28]. Some studies have explored their use in waste management; however, only a few have considered their integration into a sustainable procurement plan [29]. As for construction waste management in Libya, the current main solution is to pile it. The country follows a 'take-make-dispose' model with little consideration for whether materials can be reused or for the feasibility of organizing a recycling process. Indeed, vast quantities still end up being buried or burned, thereby polluting local air and water sources [30]. Similarly, Lean Construction Theory, which emphasizes efficiency and waste reduction, has been widely implemented in developed nations but remains understudied and underutilized in Libya. JIT procurement and value stream mapping to date have focused on reducing waste during construction. The reduction of waste at source is an area that has yet to be studied or implemented, although it is closely related to these two principles [31].

4.4. Weak policy and regulatory support for sustainable procurement in Libya

Another critical gap in the literature concerns regulatory and policy frameworks, which either hinder or encourage sustainable procurement in Libya. In a developed country where the end users are often government bodies that ought to comply with the sustainable requirement in terms of materials used that are more resource-friendly in providing more recycled content, there is hesitation toward accelerating the process of green procurement in civil and construction works, which is an area where government policies could foster adherence [32]. However, in Libya, the regulatory pressures on firms to adopt sustainability procurement strategies are marginal, and the Libyan market is characterized by procurement practices that are primarily cost-driven and less concerned with sustainability [33]. Further studies are needed to analyze policy changes and policy tools aimed at promoting sustainable procurement behavior in Libya's construction sector, which helps to fill the aforementioned gap.

4.5. Insufficient empirical data on procurement practices in Libya

Most studies on sustainable procurement and waste management are rooted in practices adopted by developed economies, which employ very different regulations, technologies, and industry practices than those in developing countries [34]. The scarcity of empirical data on procurement practices, material selection criteria, and construction waste generation remains a notable issue in Libya [11]. It limits the capacity to design tailored, localized solutions that enhance procurement efficiency and reduce waste. Current research on Libya starkly highlights general issues in construction waste management rather than the relationship between procurement and waste minimization [35]. More empirical studies are required to evaluate procurement inefficiencies, identify specific barriers, and determine solutions tailored to more sustainable procurement in Libya´s waste management context. Available empirical estimates indicate that construction and demolition waste already constitutes a substantial share of municipal solid waste streams in major Libyan cities; for example, Ali [35] reports that CDW accounts for a large proportion of total waste in Tripoli, Benghazi, and Misrata, with most material sent directly to uncontrolled landfills or open dumping sites. Recent multi-criteria analyses by Alossta et al. [36]. further show that landfilling remains the dominant option in Libyan CDW management portfolios, with recycling and reuse scenarios still marginal.

4.6. Limited stakeholder collaboration in sustainable procurement

Although stakeholder engagement plays a critical role in the success of sustainable procurement initiatives, few studies examine stakeholders' roles in integrating procurement with waste management in Libya [36]. A review of the literature suggests that the effective implementation of green procurement strategies requires coordination among relevant parties, including government agencies, contractors, suppliers, and environmental organizations [37]. However, in Libya, there was limited stakeholder collaboration, resulting in a lack of motivation for suppliers to deliver sustainable materials and low client demand for a green construction process [33]. This also highlights the lack of research examining how effective engagement and collaborative procurement models can help initiate sustainability initiatives in the Libyan construction industry. As shown in Table 2, this study addresses the gap by applying Stakeholder Theory to enhance collaboration and multi-actor coordination for sustainable procurement and waste management.

5. Conceptual framework development

It is essential to incorporate sustainable material sourcing into construction waste management to reduce material waste, improve resource efficiency, and increase the sustainability of construction firms. A conceptual framework is proposed to link procurement techniques, green construction activities, technology adoption, and waste management performance. The critical sustainability theories on which it is founded include Lean Construction, Circular Economy, Institutional Theory, and Stakeholder Theory, each emphasizing waste minimization, resource efficiency, and collaborative decision-making [4, 5]. The interconnectedness of sustainable procurement, cross-industry partnerships, and efficient waste management, facilitated through technological innovation, is emphasized throughout the framework. The conceptual framework is therefore designed as a direct response to the gaps revealed by the bibliometric mapping and gap analysis—namely, the separation of SMP and CWM research streams, the limited representation of Libyan and similar contexts, and the under-theorization of how procurement, green building practices, and digital technologies jointly shape waste indicators.

Because the framework is theory-driven and grounded in secondary evidence, a structured validation programme is needed. In the Libyan context, this could include: (i) expert workshops with policymakers, contractors, and suppliers to refine the framework components; (ii) pilot application in a small number of public construction projects, where procurement criteria and waste indicators are monitored before and after framework adoption; and

Table 2. Identified gaps in literature and contributions of this study.

Challenge Identification	Methodology	Key Findings	Stakeholder Identification	Engagement Strategies	Reference
Managing divergent stakeholder interests, complex collaboration, and expectation balancing.	80 semi-structured interviews across 13 European companies.	Identified 8 key stakeholder roles critical to sustainability-oriented innovation (SOI).	8 stakeholder roles: stimulator, initiator, broker, concept refiner, legitimator, educator, enabler, impact extender.	Assign specific roles to stakeholders for targeted engagement in SOI.	[38]
Legal uncertainty, slow permitting, and balancing sustainability goals in planning.	Case study of a mining project; focus on early-phase governmental engagement.	Government collaboration improves legal clarity and project quality.	Governmental bodies in industrial engineering projects.	Establish structured engagement guidelines.	[39]
Misalignment between multinational strategies and local sustainability needs.	Case study using stakeholder and institutional theory.	Aligning operations with SDGs requires localized engagement and leadership.	Local stakeholders in developing economies.	Foster leadership and responsive adaptation to local contexts.	[40]
Barriers in green procurement: conflicting interests, power gaps, poor communication.	Integrated MEREC–CODAS model.	CSE improves public-private green procurement outcomes.	Diverse sector actors with conflicting roles.	Invest in stakeholder capacity building.	[41]
Community collaboration gaps in social enterprise efforts.	Qualitative case study in Pakistan.	Stakeholder collaboration enhances civic wealth.	Social enterprises and local beneficiaries.	Collaborative frameworks for civic impact.	[42]
Divergent visions, weak planning, poor resource use, cultural gaps.	Workshops across 38 projects with 128 participants.	Participatory methods address vision misalignment and improve resource use.	Multi-sector stakeholders (academia, civil society, business, government).	Conduct participatory workshops and align goals.	[43]
Limited stakeholder engagement to address systemic sustainability issues.	Stakeholder theory analysis.	Stakeholder participation is vital to sustainability transitions.	Influential stakeholders across sectors.	Promote participatory processes and transparent reporting.	[44]
Displacement and socio-economic issues in tourism development.	Conceptual framework on stakeholder roles in tourism.	Public-private partnerships support sustainable tourism.	Tourism developers, government, locals, private sector.	Encourage joint infrastructure planning.	[45]
Poor coordination in humanitarian supply chains.	TCCM framework, stakeholder theory.	Proposed a performance-oriented stakeholder framework.	Humanitarian actors and logistics partners.	Integrate data tools and cross-sectoral dialogue.	[46]
Conflict in supply chains; need for practical stakeholder management.	Development of stakeholder collaboration framework.	Strategic ambiguity can convert conflict to collaboration.	Key stakeholder groups in sustainability supply chains.	Use ambiguity strategically to manage disputes.	[47]

(iii) longitudinal case studies comparing projects that apply SMP–CWM integration with those that follow conventional procurement. The resulting empirical data would allow quantitative testing and calibration of the proposed linkages.

5.1. Sustainable material procurement and waste reduction

By helping to select, obtain, and manage materials throughout the project, sustainable material procurement plays a crucial role in minimizing construction waste. One significant factor contributing to material wastage is inefficient procurement practices, including over-ordering, selecting the wrong suppliers, and improper supply chain management [48]. Just-in-Time procurement strategies offer an excellent solution to these challenges, as they prevent the hoarding of materials, thereby reducing the risk of damage and the need for further disposal of materials and goods [49]. Just-in-time procurement minimizes the risk of inappropriate storage or mismanagement by ensuring that materials are delivered precisely when needed. Supplier selection is an essential aspect of sustainable procurement. Contractors and procurement managers need to rank suppliers who adhere to, at the very least, the principles of reducing waste, recycling materials, and sourcing sustainably [50]. Sustainable Suppliers are essential in the circular economy because they provide construction materials that are either recyclable or reusable at the end of their life cycle [51].

On the other hand, procurement decisions that overlook sustainability objectives, focusing instead on cost, not only result in more construction waste but also lead to greater environmental degradation [52]. Another extension of this role is managing waste purchasing, based on the principle that procurement is responsible for minimizing material waste. Waste purchase management is more effective when it focuses on optimizing material orders, preventing over-purchasing, and ensuring materials are purchased in line with accurate project requirements [53]. Poor delivery management and over-purchasing consume resources inefficiently, thereby increasing project-related costs and ecological impacts. Strategies for digital procurement tracking, with access to historical data analytics, can improve forecasting of materials and mitigate waste that is ill-fitted to the respective stakeholders [54].

5.2. Role of green building practices in waste management

Sustainability in construction, along with resource efficiency and the use of sustainable materials, serves as the bridge between procurement strategies and effective waste management, thanks to green building techniques. Sustainable construction is incentivized through green procurement policies and regulatory frameworks that require sustainable practices, as outlined in procurement frameworks with waste reduction targets [55]. Stringent environmental regulations and certification systems worldwide have made it necessary to use recycled, environmentally sustainable construction materials. The implementation of these policies has proven successful, as the industry has shifted its approach to seeking more sustainable procurement strategies and improved performance in waste management [56]. Legislative support is another factor influencing green building practices in waste management during construction. Sustainable promotion, environmental compliance, and incentives for green materials are regulatory policies that support better procurement decisions [57]. The lack of robust regulatory frameworks and ineffective enforcement of policies has hindered the widespread adoption of sustainable procurement in Libya [11]. Having clear guidelines for legislative policies and providing financial benefits to construction companies that choose sustainable measures can give them a foothold in environmentally positive procurement techniques. By focusing on awareness programs, we can create a greater impact in promoting green building practices. All new green building practices can focus on sustainable procurement, waste reduction, and best management practices for construction waste. Dealing with procurement, contractors, and suppliers should be educated about the advantages of adopting sustainability-driven procurement policies and about long-term waste reduction in construction [58]. Awareness-raising at the industry level, including the implementation of regulatory mechanisms, can foster a culture of sustainability in which procurement decisions prioritize waste reduction and the efficient use of resources.

5.3. Construction technological integration for waste optimization

Incorporating advanced technologies in procurement and waste management helps improve procurement efficiency, decrease waste, and facilitate sustainable construction processes. Among these digital tools, Building Information Modeling (BIM) has been recognized as having the most significant potential to improve procurement and reduce material waste [59]. BIM minimizes the over-ordering of materials and the disposal of excess materials by enabling construction professionals to assess material requirements, manage material inventory in real-time, and make informed procurement decisions [52]. BIM technology facilitates effective procurement planning by enabling efficient sourcing of materials tailored to project needs, thereby minimizing procurement-related waste. Providing professional development training programs in BIM and the digital procurement system is vital to ensure construction personnel are prepared to implement technology-driven waste management strategies [60]. Third, digital procurement tools enhance material estimation, reducing errors that lead to excess material consumption and budget overruns, as well as excess waste [4]. This incorporates robots and smart tracking, alongside and beyond BIM and AI-enabled modelling and forecasting tools, to standardise the approach to resource efficiency and waste reduction [61]. By deploying Internet of Things (IoT) sensors along construction supply chains, construction companies can monitor material usage, transportation efficiency, and waste generation trends in real time. Such insights, based on data, enable construction firms to make informed decisions on procurement that align with their sustainability goals, thereby reducing material waste and enhancing the cost-effectiveness of projects [62].

5.4. Construction waste management effectiveness

The primary objective of the conceptual framework is to enhance the efficiency of construction waste management by combining sustainable procurement practices with innovative technological solutions. Several significant measures of waste management effectiveness include waste minimization, recycling rates, material reuse, landfill avoidance, and procurement cost avoidance [63]. This enables construction companies to transition their procurement strategies from a reactive waste-disposal approach to a proactive, sustainability-oriented model, aligning with green building practices and technological advancements. This also ensures that procurement is not an afterthought in waste management. Rather than waste management being integrated into the overall project's decision-making process from the start. However, it is also necessary to strengthen regulatory oversight, foster collaboration with stakeholders, and adopt new digital procurement technologies if the industry is to drive more efficient and resource-saving construction. This framework will need to be delivered by policymakers, industry leaders, and construction labourers to minimize construction waste and promote sustainable procurement.

5.5. Conceptual framework model

Conceptual framework model establishing a process to integrate sustainable material procurement (SMP) into construction waste management (CWM). It highlights the linkages among procurement approaches, green building methods, technological innovation, and waste management efficiencies, aligning procurement guidelines with sustainability objectives [64]. The core of sustainability is sustainable material procurement, encompassing suppliers' waste commitments and efficient purchasing, as well as Just-in-Time (JIT) procurement to avoid over-ordering and material waste [65]. Construction firms can also reduce their environmental impact and enhance resource efficiency by working with sustainable suppliers and using eco-friendly materials. Sustainable building methodologies connect procurement and disposal by influencing government practices, sustainable construction approaches, and stakeholder awareness [64]. In other words, legislation with strong support is beneficial to firms in implementing green procurement strategies, whereas weak enforcement in Libya is a barrier to green procurement [33]. Increased awareness is also necessary to promote compliance and ultimately adherence to sustainable procurement practices. Appropriate technologies can be used to enhance procurement efficiency through BIM-based procurement, AI-based forecasting, and IoT-based material tracking [66]. These tools facilitate easier sourcing and procurement decisions, reduce the need to display unused materials, and enable better collaboration among stakeholders. By utilizing a real-time, monitor-enabled digital procurement system, material accounting and waste generation can be effectively tracked, allowing the implementation of proactive waste management strategies.

The ultimate goal is to assess the effectiveness of waste management in terms of the amount of waste to be reduced, recycling efficiency, reliance on landfills, and associated costs. Fifteen years ago, several studies found that aligning procurement with waste management goals enables firms to shift from a reactive, waste-disposal perspective to a proactive, sustainability-based procurement model [67]. The SEI is a conceptual model that graphically illustrates the roles procurement, green building practices, and technology play in advancing sustainability in the construction sector. It entails a guide to align sustainable solutions through procurement, optimizing material innovation, and promoting stakeholder engagement and the circular economy. It needs to be an enforced policy, with the allocation of the appropriate digital procurement technologies to the public procurement market, and creating an environment and awareness for sustainability that can help the Libyan construction sector become sustainable.

5.6. Expected outcomes of the framework

The conceptual framework proposed in this study can enhance sustainability by integrating sustainable material procurement (SMP) into construction waste management (CWM) to improve waste reduction, procurement efficiency, and practices in the construction industry. It thus aligns procurement choices with environmental and economic objectives, within which the use of materials is minimized, waste is reduced, and sustainability goals are achieved [68]. One of the primary anticipated benefits is a significant reduction in construction waste, achieved by enhancing procurement planning, selecting suitable suppliers, and improving resource efficiency. With the implementation of Just-in-Time (JIT) procurement and digital material-tracking systems in industries, construction firms can prevent over-ordering, avoid excess materials on-site, and avoid incurring disposal costs [52]. This prevents waste from being sent to landfills and promotes the circular economy by using recyclable, sustainable materials. This also includes green buildings through regulatory frameworks, compliance, sustainability certification, and awareness. However, stricter implementation of environmental policies and industry standards prompts construction firms to adopt sustainable procurement practices, thereby reducing environmental degradation and improving the sustainability of the entire project. Awareness among all stakeholders, including contractors, suppliers, and policymakers, fosters a culture of sustainability and further strengthens their commitment to sustainable material sourcing and waste-conscious procurement practices. Another important outcome is technological integration, as the framework paves the way to the traditional adoption of BIM, AI-based procurement forecasting, and IoT-based material tracking systems. Digitalized solutions work with objects that require lower procurement precision, the redeployment of materials flows, and the increased use of data-driven decision-making [69]. A firm can leverage technology in procurement and waste management to track real-time material consumption, anticipate trends in waste generation, and proactively minimize waste. The anticipated output is an improved performance of CWME. This framework enables firms to minimize disposal-related expenses, maximize material reuse and recycling rates, and reduce their reliance on landfills. Sustainable procurement enhances the cost-effectiveness of waste management strategies, operational efficiency, and compliance with sustainable development goals. In general, this framework provides a systematic process for achieving waste minimization, optimizing resource consumption, and integrating sustainability into the Libyan construction industry. For this tool to be successfully applied, however, it will require proper policy support, cross-industrial collaboration, and technological investment—the crux of successful execution being whether procurement practices can facilitate an energy-efficient and sustainable construction sector [70].

5.7. Mediating role of technological integration in CWM

The integration of tools and automation presents a practical approach to improving operational efficiency in the construction industry. These technologies support streamlined procurement processes, reduce material wastage, and enhance overall waste management practices. The mediating role of technological integration in the relationship between sustainable material procurement (SMP) and the effectiveness of construction waste management (CWME) is illustrated in Fig. 9. This figure illustrates how technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT) support sustainable procurement strategies, leading to more effective waste management outcomes. The mediating role of technological integration between sustainable material procurement (SMP) and construction waste management effectiveness (CWME). The implementation of several technologies, including Building Information Modeling (BIM), artificial intelligence (AI), the Internet of Things (IoT), and innovative waste-tracking systems, enables firms to transition from traditional, reactive waste management practices to proactive, data-driven sustainability strategies [71]. Technological integration mediates CWM rather directly, primarily through the BIM-driven material estimation and procurement planning. With BIM, construction professionals can accurately compute the material quantities needed; as a result, this also minimizes material ordering and maximizes resource utilization. Construction companies can prevent procurement-related waste and improve efficiency by incorporating BIM into their procurement systems, as they can monitor the usage of materials throughout the lifecycle of the project. This will lead to reduced waste, improved stock management, lower disposal costs, and increased efficiency in waste management. The connection between procurement and waste can also be reinforced through the use of AI-powered predictive analytics, enabling construction companies to predict material consumption patterns, as well as waste generation and procurement schedules [72]. Using AI algorithms to review the firm's past procurement records helps identify regularities of over-procurement, refine procurement plans, and select sustainable materials with low potential for waste. AI helps enhance procurement accuracy, reducing the likelihood of surplus materials or disposal, and supports sustainable waste management initiatives.

Contextualized IoT in construction real-time material-tracking systems provides additional mediation, as materials entering the construction site can be monitored alongside measured waste [73]. Automation of these processes through IoT sensors enables on-site receipt and consumption of materials, as well as waste disposal, allowing real-time monitoring of sensitive, minimal data and synchronizing procurement and waste management processes. This fosters greater transparency and accountability, enabling more informed decision-making regarding prevention and recycling. Inevitably, on-site smart waste management solutions arrive with their recycling systems in place, including automated waste-sorting systems, which foster a unique culture of waste reduction & improved resource use. AI–based systems can be instrumental in separating recyclables from non-recyclables, as well as offer technology to separate construction waste based on the type of material with seamless efficiency [72]. Thus, it enables recycling, reduces reliance on landfills, and promotes sustainability.

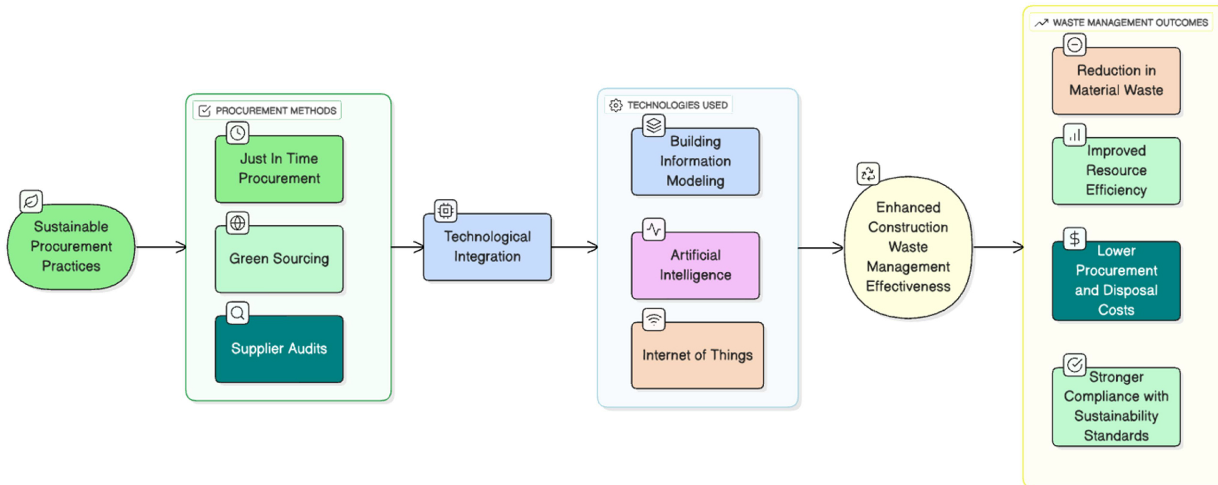

Fig. 9. Integration of sustainable procurement and technology for effective construction waste management.

Examples of these technologies can be implemented in CWM, enabling efficient waste treatment with minimal environmental impact and cost-effective processes. Fig. 9 provides a visual summary of the linkages between technological enablers, sustainable procurement, and improved construction waste management. Finally, technology integration links procurement strategies and waste disposal, encompassing materials sourcing, usage, and disposal capabilities [74]. The enabling role of investment in digital infrastructure, expenditure on human capital, and sound policy frameworks is necessary to facilitate the successful adoption of these technologies in the construction sector. Procurement and waste management tools, along with automation, enable construction corporations to become more eco-friendly, reduce costs, and enhance environmental sustainability.

5.8. Green building practices as a mediator for stakeholder awareness and construction waste management (CWM) outcomes

The need for more attention to green building practices from construction stakeholders serves as a significant mediating role between construction stakeholder awareness and waste management strategies, aiming to achieve environmentally friendly values, ensure procurement, and promote regulatory compliance and sustainable construction [75]. Green building practices provide a control framework that connects stakeholders, including contractors, suppliers, policymakers, and construction professionals, through legislative support, industry standards, and sustainability awareness programs, enabling the implementation of synergistic waste management practices aligned with sustainability objectives. Embed green building in the procurement and construction processes in order to support waste reduction actions and material efficiency, and environmental goals [76]. One of the most vital leverage points for driving sustainability in construction waste management is stakeholder awareness. Stakeholder education, along with sustainable procurement, waste reduction techniques, and green construction methods, can promote the adoption of these practices and compliance with waste management policies [77]. Through awareness programs and training initiatives, stakeholders become more aware of the sustainability practices guided by the industry, thereby fostering a culture where green procurement, sustainable material sourcing, and waste-conscious decisions are prioritized. However, the awareness is not enough and would only be piecemeal if not backed by green building policies and regulatory enforcement tools that enforce sustainable procurement and construction activities [78].

Green building practices serve as the bridge that ensures stakeholder awareness translates into effective waste management outcomes. The enforcement of sustainability mandates through regulatory policies is one aspect of this accountability, reflected in the need for construction companies to undergo sustainable building certifications and formulate plans for the use of green materials and waste reduction, for their policies to comply with the prescribed parameters. Green building standards, when translated into guidelines, provide stakeholders with a well-defined framework for sustainable waste management throughout the procurement and construction processes [79]. Even with awareness, mechanisms to address the issue are lacking due to the absence of regulations. Without

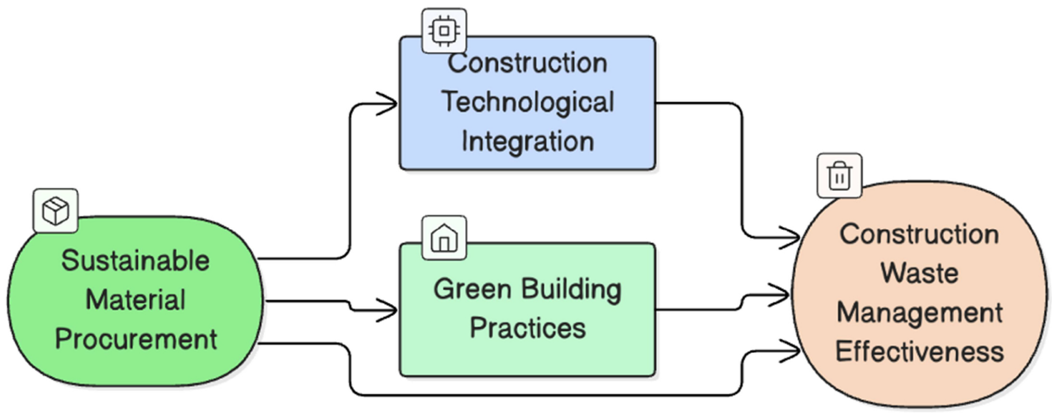

Fig. 10. The conceptual framework diagram.

clear rules to follow and enforce, most construction firms will not make an effort to adopt sustainable or green procurement and waste management practices. Legislative frameworks and sustainability guidelines go even further to ensure that stakeholders progress from awareness to practice and engage in waste minimization. Enforcement of building codes that mandate the use of recycled materials and appropriate waste management aids firms in integrating GP into their purchasing policies [80]. In addition, some firms are being encouraged to adopt sustainable material sourcing programs, construction waste recycling programs, and other similar initiatives due to certain tax benefits, sustainability certifications, and financial grants. It is, therefore, an alternative means of putting theory into practice with sustainability efforts in the construction industry via green building practices.

Integrating stakeholder awareness and green building practices into construction works also helps make construction waste management more effective, as people come together to ensure that procurement, material use, and waste disposal align with sustainability objectives. The aforementioned integration offers several advantages, including reduced material use, improved recycling efficiency, decreased reliance on landfills, and cost savings through consolidated procurement. Firms that follow green building policies enjoy not only enhanced environmental performance but also improved reputation, regulatory compliance, and long-term operational efficiency. As more construction firms adopt green procurement strategies, the waste management system will become more systematic and aligned with the principles of a circular economy. However, green building practices are the primary mediator between stakeholder awareness and advancements in waste management. It works to embed waste minimization and resource efficiency in the practices of construction firms, suppliers, and policymakers by employing an integrated framework of education, regulation, and sustainability incentives [81]. These findings suggest that for stakeholder engagement to have a greater impact on construction waste management outcomes, it must be combined with strengthened implementation of green building policies, enhanced regulatory enforcement, and expanded sustainability awareness programs. Based on current trends, the long-term sustainable development of the construction sector requires engaged and informed stakeholders interacting with a robust green building regulatory framework to drive the adoption of sustainable practices in the construction industry.

5.9. Conceptual framework

The conceptual framework (Fig. 10) illustrates the relationships among stakeholder awareness, green building practices (GBP), sustainable material procurement (SMP), construction technological integration (CTI), and construction waste management effectiveness (CWME) [82]. The model illustrates the co-relationship among adapting procurement strategies, regulatory measures, and technological breakthroughs, which together underpin efficient resource utilization and waste reduction, thereby advancing sustainability in the construction sector. Stakeholder awareness is a crucial factor in sustainable construction waste management. Efforts to disseminate information on sustainable procurement strategies and the reduction of construction and demolition waste can serve as an eye-opener for stakeholders, such as contractors, suppliers, policymakers, and industry practitioners, to adopt green building practices and comply with regulatory requirements. However, stakeholder awareness can achieve the above only if it is strongly supported by stringent green building policies, industry regulations, and financial incentives to encourage sustainable practices [83]. Green building practices act as a mediator between awareness and the waste management strategies you are willing to adopt. Such practices encourage sustainable procurement, the use of eco-friendly materials, and adherence to sustainability-based certification programs. Green building practices enhance the connection between stakeholder knowledge and waste management efficiency outcomes by enforcing robust building codes, providing sustainability incentives, and embedding sustainability-focused procurement and purchasing policies.

The responsible selection and acquisition of materials play a direct role in minimizing waste through efficient sourcing, selection, and management. Procurement strategies, including JIT material delivery, supplier waste-reduction commitments, and responsible sourcing of green materials, help avoid over-ordering and material waste, thereby reducing the environmental impact associated with construction projects [4]. However, to achieve procurement efficiency, technological support is necessary; therefore, technology integration in construction is a crucial part of the structure. For example, integrating construction and technology presents a challenge that forces the AEC industry not only to digitize but also to automate and analyze data to improve effectiveness in procurement and waste reduction. Tools such as Building Information Modeling (BIM), AI-based forecasting systems, and recorders for material tracking related to IoT support to improve procurement accuracy, reduce forecast production of waste, and the real-time monitoring of material consumption [84]. These ICT enablers reduce waste by more effectively managing inventories, thereby eliminating procurement-based waste and optimizing material flow sequencing across construction.

The overall purpose of the framework is to enhance the effectiveness of CWMS in meeting sustainability performance targets, such as minimizing waste, improving recycling efficiency, reducing reliance on landfilling, and achieving savings through better procurement, among other objectives. By adopting sustainable procurement practices, green building policies, and modern digital technologies, construction companies can transition from waste management to more sustainable approaches [56]. These interconnecting relationships are illustrated in the visual model of the framework, which shows how stakeholder awareness leads to the adoption of green buildings, which in turn facilitate public procurement and technological advances to achieve effective waste management. The framework establishes a holistic guideline for the construction industry to integrate sustainability concepts into procurement and waste management.

6. Practical implications

The practical implications of introducing sustainable material procurement (SMP) into construction waste management (CWM) are substantial for stakeholders in the construction business (construction firms, policymakers, suppliers, and practitioners). Sustainable procurement, technological development, and a regulatory framework can enhance waste management and resource efficiency in the construction sector by deploying and integrating these strategies, thereby promoting long-term environmental sustainability. Adopting new eco-friendly practices is crucial to addressing current material-use inefficiencies, reducing waste, and achieving economic and environmental benefits in the construction industry. For construction companies, purchasing sustainable materials is considered one of the few opportunities to reduce costs associated with heavy material waste, disposal, and transportation expenses within the supply chain. Digital procurement solutions, such as BIM and IoT-enabled tracking, can significantly reduce material waste by enabling efficient inventory control and just-in-time ordering. Additionally, compliance with green building certification systems can enhance project marketability, attract green investors, and improve project lifecycle performance [85].

The implications for policymakers and regulators are that proactive environmental policies, such as sustainable public procurement and waste management, should be developed. Additionally, policies should facilitate access to and use of green materials while motivating firms to innovate and adopt new eco-material technologies. Government interventions, such as tax credits and subsidies for green purchasing, could motivate widespread industry adoption and facilitate a transition to a circular construction approach. For suppliers and manufacturers of materials, the transition to sustainable procurement also implies a shift in market demand towards new, low-CO_2, recycled, and recyclable construction materials. Suppliers' production strategies should align with sustainable development goals, and suppliers should provide eco-friendly substitutes while maintaining transparency regarding their supply chain. Establish relationships between materials suppliers and contractors, leading to improved resource allocation, reduced waste, and more efficient project delivery [86].

Additionally, training and capacity-building programs are needed for industry professionals and the construction labour force on sustainable procurement and waste management. Educating professionals about emerging technologies, such as AI for waste prediction and blockchain for supply chain transparency, can facilitate the proper execution of sustainable procurement strategies [87]. Construction managers and site supervisors should have sufficient resources at hand to consider sustainability in the decision-making and planning process, as this can impact procurement options and opportunities for managing site construction waste. Ultimately, the managerial implications of incorporating SMP within CWM highlight the convergence of sustainable procurement, technology adoption, and regulation. Linkages among industry players, policymakers, and academia are necessary for the successful implementation of sustainable waste management initiatives. Through innovation, regulation, and knowledge transfer, the construction sector can make significant strides in reducing material waste and improving resilience. From a regulatory perspective, the findings highlight the need for Libya to move from generic environmental provisions to explicit legal requirements for sustainable public procurement and construction waste management. This could include revising public procurement law to mandate the use of green criteria (e.g., recycled content, life-cycle environmental performance, and waste-reduction plans) in tender evaluation, as well as embedding minimum standards for construction and demolition waste segregation, on-site handling, and recycling in building codes. Clear enforcement mechanisms, such as mandatory waste management plans for large projects and penalties for non-compliance, are essential to address the current weak regulatory pressure on firms.

Targeted economic incentives can complement regulatory reforms by reducing the perceived cost burden of sustainable procurement in Libya's construction sector. Examples include tax credits or accelerated depreciation for investments in recycling facilities and digital procurement systems; reduced permit fees for projects that meet certified green building and waste-reduction benchmarks; and preferential access to public tenders for contractors that demonstrate certified sustainable procurement practices. Such instruments can gradually shift the market from lowest-price, linear purchasing towards value-for-money decisions that internalise waste and environmental costs. Institutional capacity building is equally critical, given Libyan agencies' and firms' limited experience with integrated SMP–CWM approaches. Establishing a specialised sustainable procurement unit within the relevant ministry (e.g., housing or public works) could provide central guidance, standard documents, and training for public procurers. At the industry level, continuous professional development programmes for procurement officers, project managers, and site supervisors covering circular economy principles, green tendering, BIM-enabled material estimation, and digital waste tracking would strengthen the human capital needed to implement the proposed framework. Partnerships with universities and professional bodies can support this through joint training, pilot projects, and the development of Libyan-specific guidelines and toolkits.

7. Conclusion

Construction is a significant contributor to environmental sustainability, but it generates substantial material waste and resource inefficiencies. In the construction industry, the sustainable procurement of materials must be integrated with construction waste management to achieve significant waste reduction, enhance resource efficiency, and enable enhanced savings, thereby leveraging the benefits of the circular economy. This paper presents a conceptual framework to raise awareness of the relationship between sustainable procurement and waste management and to provide a structured mechanism for advancing sustainability in the construction industry. The results underscore the importance of selecting environmentally friendly materials, engaging suppliers in waste reduction initiatives, and leveraging digital technologies to optimize the procurement process and waste management activities. Despite the apparent advantages, obstacles such as a lack of regulation, high implementation costs, and limited stakeholder awareness continue to slow adoption. Overcoming these barriers will require the joint efforts of politicians, industry actors, and researchers to create supportive legislation, financial incentive programs, and educational schemes that promote sustainability. This study has contributed to the literature by providing a practical approach for construction firms, the government, and material suppliers to successfully adopt sustainable procurement strategies. According to our literature review, there is still much work to be done in applying this framework to actual projects, verifying its influence in various moments and scenes, and further improving each part of this paper, based on feedback from industry and the progress of technology. By focusing on sustainability in procurement, technological innovation, and collaborative partnerships, the construction sector can minimize waste, increase cost-effectiveness, and make significant long-term contributions to broader environmental and economic sustainability agendas.

Despite its contributions, this study has a few limitations that should be acknowledged. First, as a narrative systematic review based primarily on

English-language publications indexed in Web of Science, Scopus, and IEEE Xplore, it may omit relevant work published in other languages, regional journals, or grey literature, including Libyan government reports and local technical documents. Second, the conceptual framework developed here is grounded in secondary data rather than primary empirical evidence from Libyan construction projects, so some proposed relationships among procurement practices, technological adoption, and waste outcomes remain to be tested in real-world settings. Third, although the review covers a broad period (2001–2026), rapid advances in digital technologies and evolving regulatory landscapes may quickly render certain technological or policy recommendations outdated, requiring periodic updates to the framework. A further limitation is that the quality appraisal relied on basic design and reporting criteria rather than a standardized tool such as the Critical Appraisal Skills Programme (CASP) or A Measurement Tool to Assess Systematic Reviews (AMSTAR), which future Libyan empirical reviews should adopt. On the other hand, at the policy level, existing Libyan environmental and public procurement regulations emphasize generic environmental protection and lowest-price tendering, but they do not mandate CDW segregation, recycled content, or sustainable procurement criteria in construction contracts, which contributes to the weak regulatory pressure documented in this review. These limitations suggest that future research should incorporate field studies, longitudinal case analyses, and mixed-methods evaluations within Libyan projects to validate, refine, and localize the proposed framework.

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Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used "Grammarly" software to improve the readability and language of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

All graphs and data obtained or generated during the investigation appear in the published article.

Author contributions

Ramzi Fouzi Hamad Abdullah was primarily responsible for developing the initial outline and structure of the manuscript. They conducted a significant portion of the literature review and data synthesis and were involved in drafting the initial manuscript. Safaa Najah Saud Al-Humairi made a substantial contribution to the literature review process, critically analyzing and synthesizing the collected data. Zunirah Binti Mohd Talib contributed to the final review and figure adjustments of the present work. They also played a crucial role in drafting and revising the manuscript, ensuring the content's coherence and accuracy.

Ethical approval

Not applicable.

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