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Advancing materials procurement processes in construction: a framework for optimising technology integration in SMEs' construction supply chains

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ABSTRACT

Materials procurement is a key challenge for construction SMEs, often hampered by limited resources, manual workflows, and poor communication. This study introduces a scalable framework that leverages accessible digital tools—such as mobile apps, RFID, and cloud-based systems—to streamline procurement. A mixed-methods approach, including case studies, interviews, surveys, and observations, was used to evaluate the framework across six SMEs in various construction sectors. Results showed notable gains: a 34% reduction in order processing time, a 25% drop in material waste, and a 35% improvement in inventory accuracy. These improvements were statistically confirmed and attributed to the framework's components. The model's phased rollout eased financial and training pressures, while built-in feedback loops allowed SMEs to adapt procurement practices to evolving project and supplier demands. By addressing real-world implementation barriers, the study provides a practical, validated roadmap for digital transformation tailored to SME needs. The framework not only improves cost control and delivery timelines but also enhances competitiveness in a digital construction landscape.

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Materials procurement; SMEs; technology integration; construction supply chain; RFID; GPS; digital databases

Introduction

Materials procurement in the construction sector represents a complex and multifaceted challenge, particularly for small and medium-sized enterprises (SMEs). The intricate nature of materials purchasing processes can significantly impact project outcomes, and recent research, notably the study "*Understanding the Complexity of Materials Procurement in Construction Projects to Build a Conceptual Framework Influencing Supply Chain Management of MSMEs*" (Donyavi et al. 2023b), has underscored the critical role that effective supply chain management plays in ensuring project success. Given that materials can constitute up to 70% of total project costs, any inefficiencies or delays in the procurement process can lead to substantial financial ramifications, hampering not only individual projects but also the long-term viability of SMEs within the construction industry (Sundblad and Nilsson 2018; Lazaro-Aleman et al. 2020).

A pivotal finding from previous research highlights the stark contrast in operational capabilities between large construction firms and SMEs. Large firms typically leverage integrated information technologies that allow for streamlined procurement processes, encompassing everything from order placement to on-site delivery. In contrast, SMEs—which account for over 90% of construction enterprises globally (Ala-Risku and Kärkkäinen 2006)—often operate with constrained resources and limited capacity to adopt similar technological frameworks. This gap in operational capability means that SMEs are frequently burdened by challenges such as delays in material delivery, miscommunication between suppliers and site managers, and overstocking, all of which stem from the absence of standardised procurement procedures (Business Roundtable, & Construction Industry Cost Effectiveness Project 1982;

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Bell and Stukhart 1986; Kasim 2008; Oyewobi et al. 2015). These findings align with earlier analyses, such as those by Agapiou et al. (1998a) and Sundblad and Nilsson (2018), who emphasised the disproportionate struggles SMEs face in adapting supply chain strategies due to limited financial and technical resources.

To address these challenges, the initial study proposed a conceptual framework aimed at improving the procurement efficiency of SMEs. This framework delineates the procurement process into key stages: input, purchasing, tracking, data management, and feedback (Ammer 1962; Clough et al. 2000). By breaking down the procurement process into these essential components, the framework seeks to clarify the steps involved in ordering materials, tracking their movement, and utilising feedback to optimise future orders. Despite the promise of this structured approach, the research identified a significant barrier: the limited adoption of technology among SMEs, which hampers their ability to achieve greater efficiency in materials management (Navon and Berkovich 2006; Cai et al. 2009).

A growing body of research suggests that modular construction can offer solutions to some of these supply chain inefficiencies by improving material predictability, reducing waste, and enhancing procurement efficiency. Parisi and Donyavi (2024) highlight how modular construction can alleviate logistical bottlenecks and enhance supply chain coordination, particularly within the UK housing sector. Their findings suggest that adopting modular approaches could offer SMEs a more structured and technologically integrated procurement process, bridging some of the gaps identified in traditional methods.

Addressing this technological gap is not only vital for improving operational performance but also essential for enhancing the overall competitiveness of SMEs in the construction sector. Building on the insights from the first study, this paper aims to operationalize and validate a technology-enabled procurement framework tailored for SMEs, with the goal of enhancing procurement efficiency, reducing material wastage, cutting operational costs, and shortening procurement cycles by exploring how advanced technologies can be effectively integrated into each stage of the materials procurement process for SMEs. The integration of technologies such as Radio Frequency Identification (RFID) for real-time tracking, digital databases for improved data management, and mobile communication tools to facilitate coordination between suppliers and construction sites has the potential to revolutionise how SMEs manage their materials procurement (Hadikusumo et al. 2005; Burns 2022). These tools have been shown to enhance supply chain transparency, an observation also supported by research on third-party logistics in construction by Anderson (1997). For instance, RFID technology can enable precise tracking of materials from the point of order to on-site delivery, significantly reducing the risk of delays and inaccuracies (Xiao and Proverbs 2002; Elkhayat et al. 2024). Further studies support the notion that efficient management of procurement processes can have a significant impact on the financial and operational performance of construction projects. Technology-driven solutions, particularly in the area of procurement, have proven to yield substantial cost reductions in large projects. However, these solutions need to be adapted to fit the constraints of SMEs, which have unique operational and resource limitations. This suggests that scalable and flexible procurement solutions, such as cloud-based systems or hybrid approaches, might be particularly beneficial for smaller firms (Cai et al. 2009; Oyewobi et al. 2015).

The practical application of these technologies within SMEs' procurement processes has shown promise in improving efficiency. Mobile apps designed to track orders and materials, coupled with cloud-based data management, can help small businesses maintain better control over inventory and deliveries, ensuring that procurement is not only more efficient but also cost-effective (Table 1982). These technologies reduce the need for physical storage and reduce the occurrence of errors, which are often prevalent in manual tracking methods (Sundblad and Nilsson 2018). Furthermore, recent advancements in predictive analytics have also shown potential in forecasting material needs, thus enabling SMEs to reduce unnecessary inventory and improve cash flow (Elkhayat et al. 2024).

Furthermore, this research will assess the practical application of these technologies within the context of SMEs, drawing on data from real-world implementations and direct observations to evaluate the impact of technology-enhanced procurement processes (Lazaro-Aleman et al. 2020). By investigating how these technological solutions can be implemented effectively within the existing framework, the

study aims to provide comprehensive insights into the potential benefits, including increased efficiency, reduced lead times, and lower costs associated with materials procurement. This research is also informed by broader studies of innovative strategies and approaches to enhancing operational efficiency in related fields, where the introduction of new methodologies and technologies has led to significant improvements in performance (Bevilacqua et al. 2017; 2018a; 2018b; Parisi and Biancuzzo 2021; Adewale and Parisi 2025).

The methodology of this study is carefully aligned with the following specific objectives to ensure a structured and systematic approach to investigating the integration of technology in SME procurement processes:

1. Evaluate the Impact of Technology Integration: This objective focuses on assessing how technologies such as RFID, digital databases, and mobile applications enhance the accuracy and efficiency of materials procurement processes—from initial order placement to on-site usage. The study examines the role of these technologies in improving visibility, inventory control, and real-time decision-making (Christopher 2022).
2. Understand Practical Barriers to Adoption: The study investigates key challenges that SMEs encounter when adopting procurement technologies, including cost implications, training needs, operational disruptions, and resistance to change. This analysis is supported by evidence from previous studies highlighting the need to tailor digital transformation strategies to SME constraints (Donyavi et al. 2023b).
3. Demonstrate Real-World Implementation Improvements: Through the practical application of the framework across six SMEs, the research evaluates tangible benefits such as reduced material wastage, improved supplier coordination, and time savings. The findings aim to validate the framework's effectiveness and encourage broader adoption by showcasing its adaptability to SME conditions (Parisi and Eger 2020; Cantafio and Parisi 2021; Christopher 2022; Parisi and Donyavi 2023).

By addressing these objectives, this study seeks to provide a practical roadmap for SMEs to enhance their materials procurement processes through technology, ultimately contributing to greater productivity and competitiveness in the construction sector. The methodological rigor also strengthens the study's contribution to the broader discourse on digital transformation in the construction industry. The insights garnered from this research will not only help SMEs improve their operational efficiency but also position them better to compete in a rapidly evolving market that increasingly demands innovative approaches to procurement and supply chain management.

Literature review

Conceptual frameworks in construction supply chains

The management of materials procurement in the construction sector is a pivotal area of study, with direct implications for project outcomes, cost control, timelines, and overall productivity. Effective materials management ensures that materials are available when needed, minimises waste, and aligns with project specifications. Various models and frameworks have emerged to streamline the construction supply chain, focusing on enhancing the coordination of materials flow, facilitating information exchange, and integrating procurement activities (Serpell and Heredia 2004; Akintoye and Main 2012; Donyavi et al. 2023b). These frameworks aim to address the inherent complexities and inefficiencies present in traditional procurement practices. Frameworks to strengthen inter-organizational collaboration have been proven effective in construction SCM (Love et al. 2002).

One of the foundational concepts in construction supply chain management is supply chain integration, which emphasises a seamless flow of materials and information between suppliers, contractors, and site managers. As highlighted by Lambert et al. (1998) and Christopher (2022), effective integration enhances alignment between supply and demand, significantly reducing delays and ensuring materials are available at the right time. This is particularly relevant for Small and Medium-sized Enterprises

(SMEs) in construction, which often struggle to achieve such integration due to limited resources and inadequate management systems (Croom 2001). The challenges faced by SMEs necessitate tailored frameworks that consider their unique operational realities (Donyavi et al. 2023a).

In previous research, a structured framework specifically designed to meet the needs of SMEs was introduced, breaking down the materials procurement process into five key stages: input, purchasing, tracking, data management, and feedback. This framework provides SMEs with a clear roadmap for managing materials effectively, reducing redundancies, and enhancing supplier coordination (Donyavi et al. 2022). While this structure may seem conventional, it has been specifically crafted to meet the unique needs of SMEs, which often face resource constraints together with challenges such as the absence of dedicated procurement teams and the reliance on manual processes (Kasim 2008). Each of the five stages—input, purchasing, tracking, data management, and feedback—has been designed to be scalable, allowing for gradual implementation that aligns with the operational realities of smaller firms. This incremental approach not only minimizes disruption but also ensures that SMEs can adopt technology at a manageable pace, addressing common barriers such as high upfront costs and the lack of technical expertise.

Technology in construction materials management

The adoption of technology has emerged as a critical driver for enhancing materials management and procurement efficiency within the construction sector. Technologies such as Radio Frequency Identification (RFID), Global Positioning Systems (GPS), and digital data management systems have been extensively studied for their potential to improve tracking, inventory management, and information sharing among stakeholders (Sun et al. 2013; Thöni and Tjoa 2017). Lack of material traceability remains a major obstacle to digital adoption in construction (Tortorella et al. 2023). Unlike BIM—often hindered by cost and interoperability issues—simpler ICT solutions may offer practical advantages (Azhar 2011).

RFID technology

RFID technology allows for real-time tracking of materials, providing construction managers with the ability to monitor the flow of materials from suppliers to construction sites. Research conducted by Navon and Berkovich (2006) demonstrated that RFID systems can significantly reduce the time spent on manual tracking, enhance inventory accuracy, and minimise material loss or theft. However, the adoption of RFID remains limited among SMEs, primarily due to concerns regarding high upfront costs and implementation complexities.

GPS and geolocation tools

GPS technology further enhances logistics management by offering precise location data for material deliveries. Studies by Maxwell and Couper (2023) have shown that GPS can assist SMEs in optimising delivery routes and reducing transportation costs. Despite its advantages, many SMEs still rely on traditional methods such as manual logs for tracking shipments, highlighting a gap in the effective integration of GPS systems.

Digital data management systems

The implementation of digital databases and cloud-based solutions can greatly streamline procurement activities, providing centralised access to order records, delivery updates, and supplier information. Improved data management facilitates better communication between SMEs and suppliers, leading to more accurate material forecasts and reduced risks of over-ordering or under-supplying. Nevertheless, challenges such as data security concerns and the need for staff training hinder many SMEs from fully adopting these technological solutions (Bello et al. 2021).

While the potential benefits of these technologies are substantial, their adoption among SMEs (Figure 1) remains limited due to financial constraints, limited technological knowledge, and a preference for traditional, manual approaches to materials management. Addressing these barriers is essential

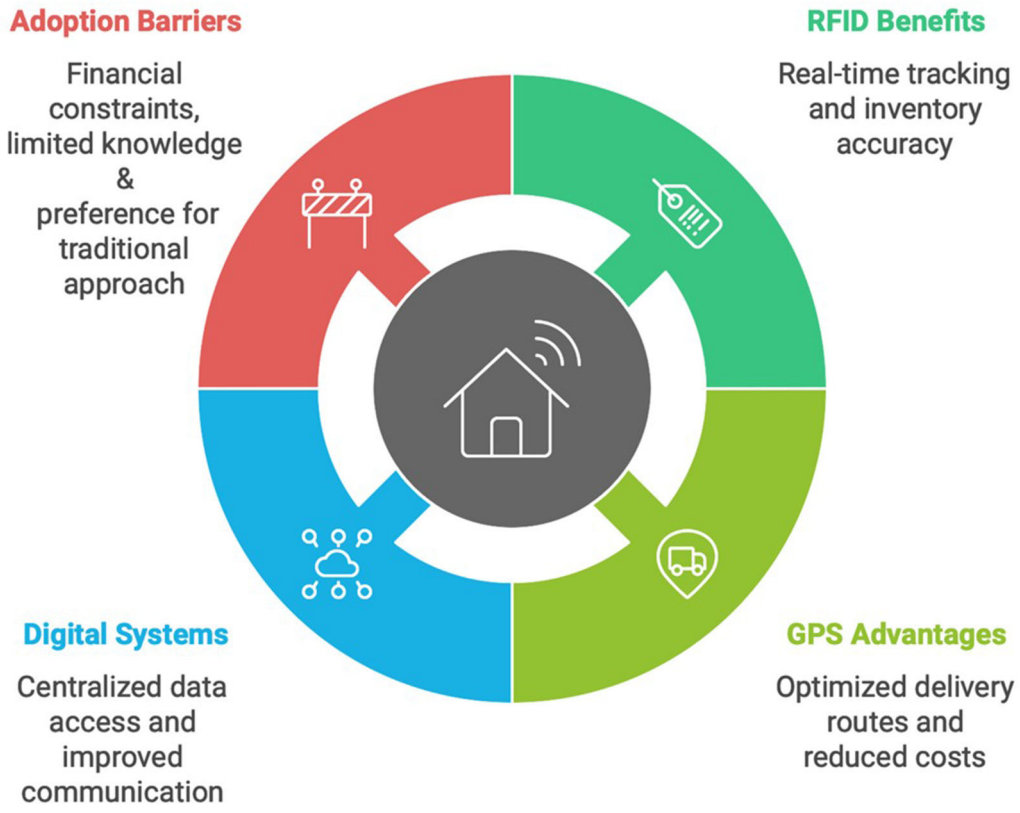

Figure 1. Technology adoption in construction SMEs. Source: Authors 'elaboration (2024).

for promoting technology adoption and improving procurement processes within the construction sector.

While emerging technologies such as blockchain and artificial intelligence/machine learning (AI/ML) have garnered increasing interest in construction management research, their integration into this study's framework was intentionally limited. This decision was based on the practical adoption constraints commonly observed among SMEs in the construction sector. Blockchain applications, although promising in terms of transparency and security, currently require a level of digital infrastructure and inter-organisational standardisation that is often lacking in small firms. Similarly, while AI/ML can support predictive analytics and automation in procurement, these tools depend heavily on large, high-quality datasets and advanced technical expertise—resources that most SMEs do not currently possess. Therefore, this study prioritises technologies such as RFID, GPS, and cloud-based data management systems, which are more accessible, cost-effective, and scalable for SMEs seeking incremental technological integration.

Importance of structured purchasing processes

A structured purchasing process is crucial for SMEs as it streamlines operations, minimises waste, and enhances overall project efficiency. Effective purchasing ensures that materials are ordered accurately, delivered timely, and used efficiently, thereby avoiding costly delays and budget overruns, which are prevalent in construction projects (Kasim 2008).

The previously proposed framework for structuring the purchasing process includes several key steps:

Input specification

Clearly defining material requirements to ensure accuracy in orders.

Purchasing coordination

Establishing effective communication channels with suppliers to confirm orders and manage delivery schedules.

Tracking

Utilising basic tracking tools to monitor shipment statuses and ensure timely deliveries.

Data management

Implementing simple digital tools to maintain records of purchases, deliveries, and material usage.

Feedback mechanisms

Creating feedback loops to adjust future orders based on real-time data and insights from past projects.

This structured approach enables SMEs to overcome common challenges in materials procurement, including poor forecasting, supplier miscommunication, and inefficient material usage (Figure 2). Research conducted by Meng (2010) suggests that structured procurement processes lead to significant improvements in supply chain performance by minimising errors and enhancing the visibility of material flows. SMEs in construction face notable supply chain risks related to finance, operations, and sustainability (Chen et al. 2025).

Adopting a systematic approach to materials management allows SMEs to gradually integrate technological solutions into their operations, facilitating a smoother transition from traditional methods to digital tools. The literature also indicates that structured processes can enhance the competitiveness of SMEs by improving their ability to meet project deadlines and maintain stronger relationships with suppliers (Khalil et al. 2019).

Framework for materials purchasing process

The framework for materials purchasing, developed in previous research, is designed to optimise the procurement processes for Small and Medium-sized Enterprises (SMEs) in the construction sector. Recognising the unique challenges faced by SMEs—including limited resources, lack of systematic approaches, and inefficiencies in supplier communication—this framework provides a structured pathway to enhance purchasing practices. By integrating technology, the framework aims to improve visibility, coordination, and decision-making throughout the materials procurement lifecycle. The key components of the framework are categorised into five stages: Input, Purchasing, Tracking, Data Management, and Feedback.

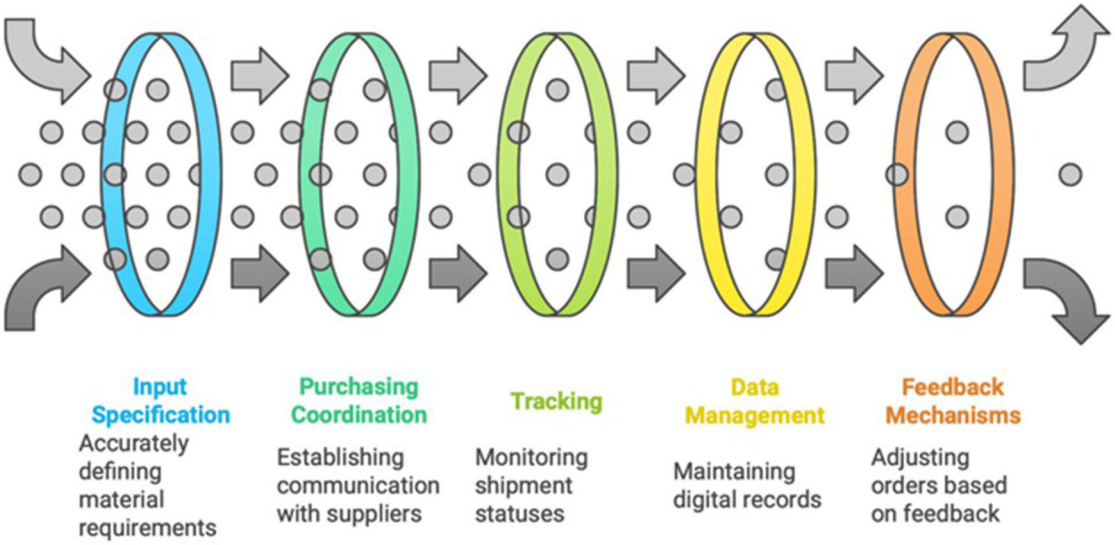

Figure 2. Streamlining SME purchasing processes. Source: Authors 'elaboration (2024).

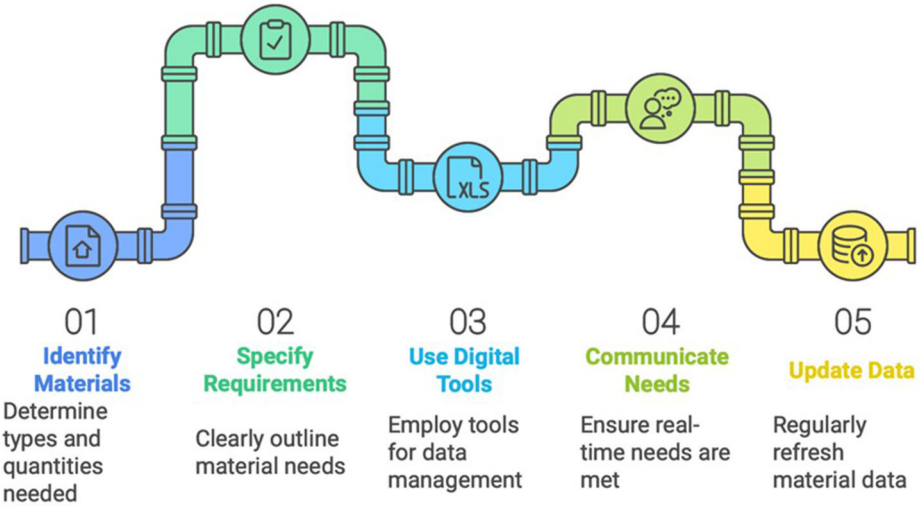

Figure 3. Procurement process for construction materials. Source: Authors 'elaboration (2024).

Input: Identification of materials and initial data requirements

The input stage serves as the foundation of the procurement process, where the types and quantities of materials required for a construction project are clearly specified (Figure 3). Accurate identification is crucial, as miscalculations can lead to material shortages or surpluses, ultimately inflating project costs (Ala-Risku and Kärkkäinen 2006; Borcherding et al. 1980). SMEs often grapple with unpredictability in project conditions and fluctuating client demands, which complicates accurate forecasting. To mitigate these challenges, the framework encourages the adoption of user-friendly digital tools—such as spreadsheets or simple database systems—to systematically gather and update data regarding material requirements as project plans evolve. Clear communication between site managers and procurement teams is emphasised to ensure that input specifications reflect the real-time needs of the construction site (Agapiou et al. 1998a).

Purchasing: Stages from order placement to confirmation

In the purchasing phase, SMEs navigate the critical steps of selecting suppliers, negotiating terms, placing orders, and confirming delivery schedules. Establishing strong supplier relationships is essential for securing timely deliveries at competitive prices (Thomas and Napolitan 1995).

> The framework advocates for a structured order placement process, incorporating standardised procedures for requesting quotes, evaluating supplier capabilities, and finalising contracts. This structured approach minimises delays and ensures optimal value in material purchases. Additionally, utilising digital communication tools, such as email templates for orders and digital tracking of purchase orders, streamlines this process, facilitating the management of multiple suppliers and ensuring timely order confirmations (Dike and Kapogiannis 2014). The various challenges highlighted in Figure 4 illustrate the complexities involved in the ordering process, resulting in time, cost, and information losses that contribute to unproductive and inefficient materials management.

Tracking: Monitoring material movement from suppliers to the construction site

The tracking phase is vital for ensuring that materials are delivered as scheduled and in the correct quantities. Delays or mis deliveries can substantially disrupt project timelines (Navon and Berkovich 2006).

> The framework highlights the potential of technologies like RFID and GPS for real-time tracking of shipments (Figure 5). While larger enterprises typically implement such technologies, many SMEs face barriers related to cost and training. The framework suggests that even basic tracking methods, such as GPS-enabled mobile apps, can significantly enhance visibility and control over material movement. To accommodate varying levels of technological comfort, this component of the framework is designed to be adaptable, enabling SMEs to scale their tracking capabilities incrementally as they gain familiarity with digital tools.

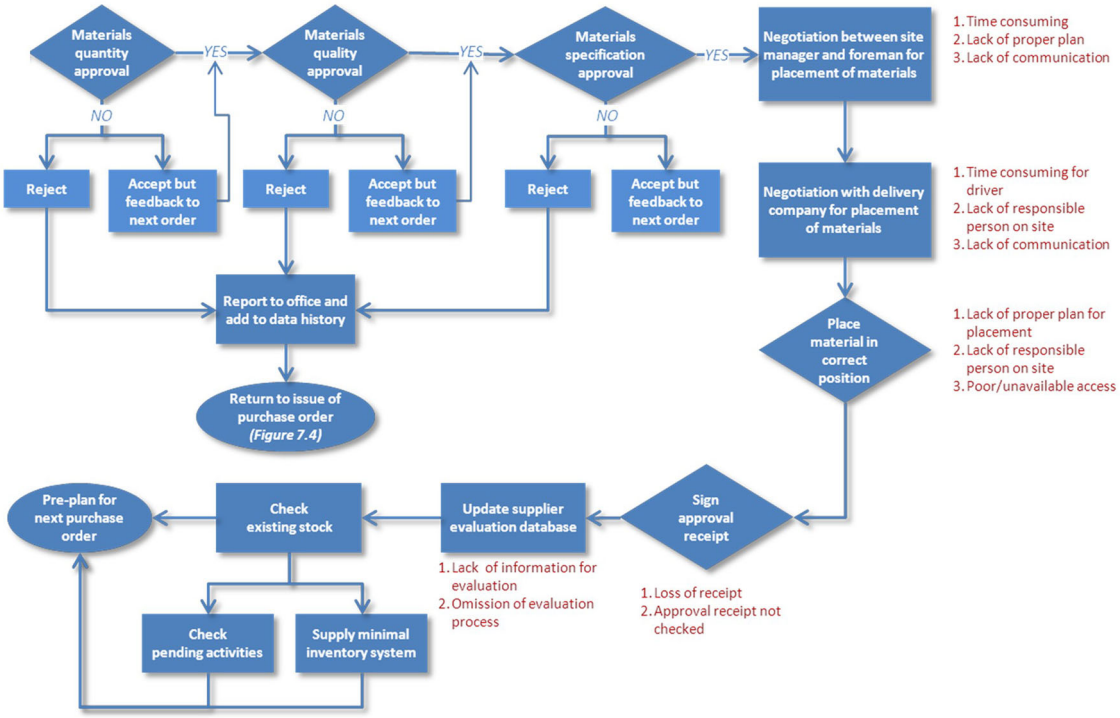

Figure 4. Ordering process and challenges faced by SMEs after delivery. Source: Authors 'elaboration (2024).

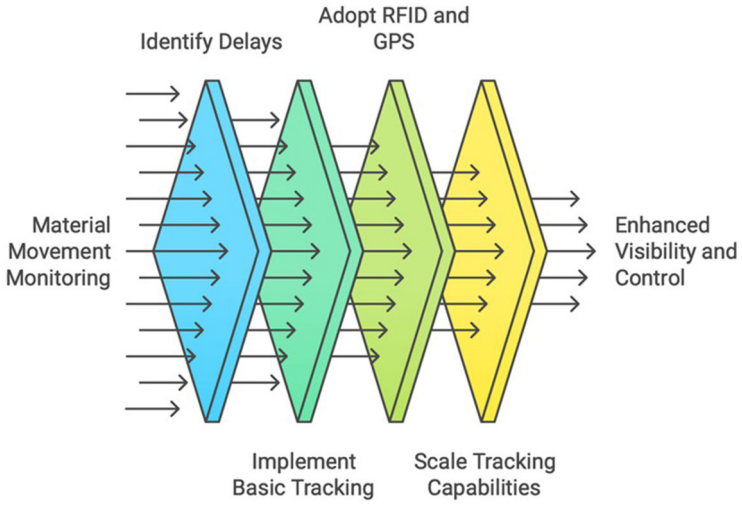

Figure 5. Enhancing material tracking in SMEs. Source: Authors 'elaboration (2024).

Data management: Handling procurement data, including order records and delivery updates

Effective data management is the backbone of the proposed framework, supported by cloud-based tools that centralize procurement data. These platforms improve real-time communication, prevent stockouts, and streamline forecasting by leveraging historical consumption trends (Figure 6), requiring meticulous maintenance of records concerning purchase orders, delivery schedules, and inventory levels. Ensuring that all stakeholders have access to current information about material statuses is paramount (Donyavi et al. 2022).

> Research indicates that many SMEs struggle with data management due to their reliance on paper-based systems. To combat this issue, the framework promotes the transition to cloud-based databases, which offer accessible, real-time data updates, thereby enhancing coordination between office

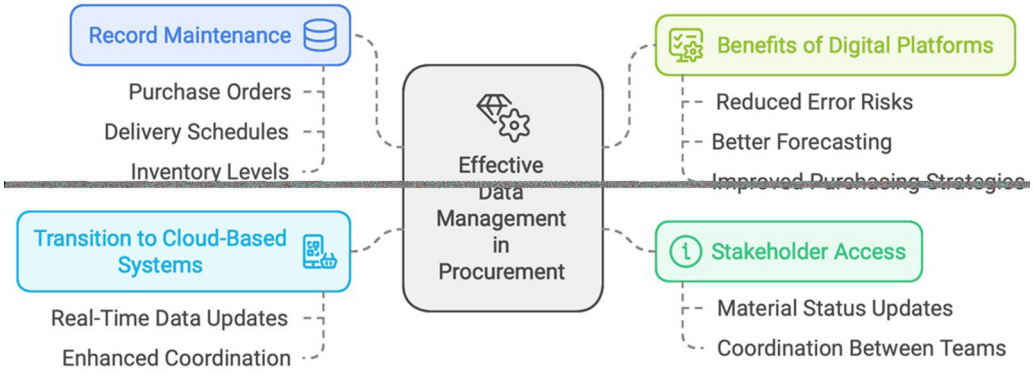

Figure 6. Effective data management in procurement. Source: Authors 'elaboration (2024).

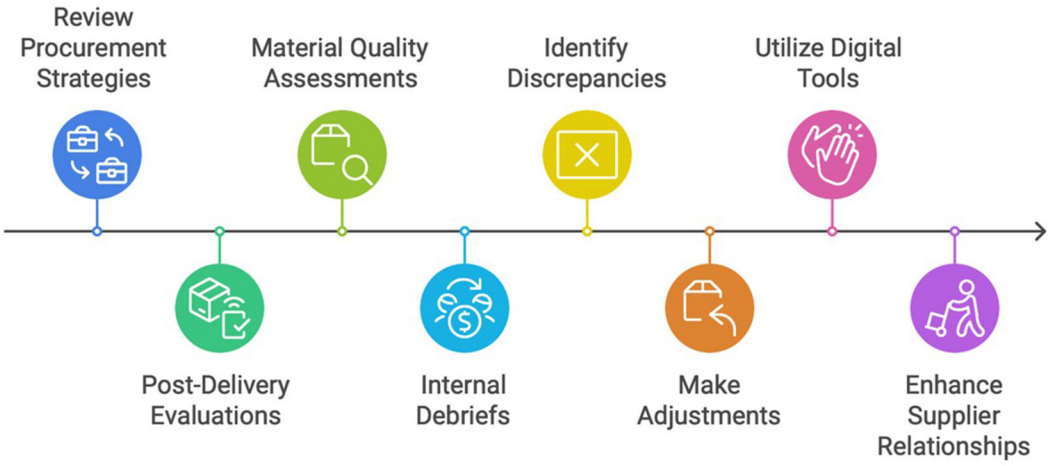

Figure 7. Feedback mechanisms in purchasing process. Source: Authors 'elaboration (2024).

staff and site managers. Digital platforms not only reduce error risks but also enable better forecasting of material needs by analysing historical data trends, allowing SMEs to adjust purchasing strategies in line with project timelines and avoid last-minute orders that can derail workflows (Borcherding et al. 1980).

In operational terms, the data management process includes the systematic recording of purchase orders, supplier contact details, delivery times, and inventory levels in structured formats, often hosted on cloud platforms such as Google Workspace or Microsoft 365. These systems enable real-time updates and shared access across team members, ensuring consistent data flow between procurement offices and job sites. Data entry responsibilities are typically distributed among procurement staff and site managers, depending on task relevance. To maintain data integrity and availability, regular backups and permission-based access controls are also recommended. As SMEs grow more familiar with digital tools, more advanced features—such as automated reorder triggers or integration with accounting software—can be introduced, further enhancing forecasting accuracy and operational efficiency.

Feedback: Mechanisms for evaluating and adjusting the purchasing process based on outcomes

The feedback component is integral for fostering continuous improvement in the materials purchasing process (Figure 7). SMEs are encouraged to review procurement strategies and outcomes after each project phase to identify areas for refinement (Bell and Stukhart 1986). Feedback mechanisms may include post-delivery evaluations with suppliers, assessments of material quality upon arrival, and internal debriefs to analyse whether purchased quantities aligned with actual usage. This iterative approach enables SMEs to pinpoint discrepancies and make necessary adjustments for future orders. The framework

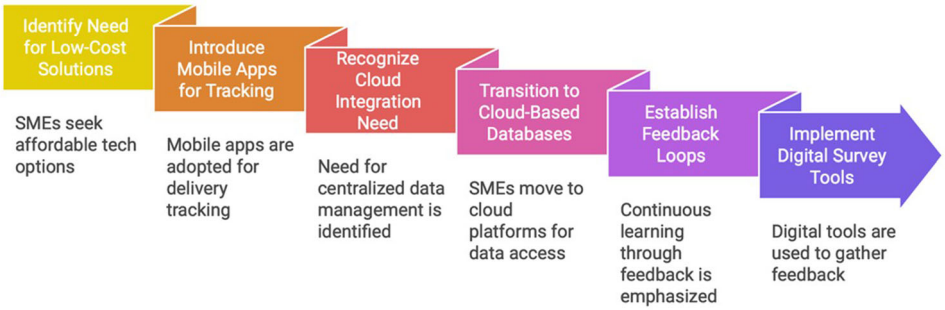

Figure 8. Framework enhancements for SMEs. Source: Authors 'elaboration (2024).

advocates utilising digital survey tools or straightforward feedback forms to capture insights from site managers and suppliers, ultimately refining procurement processes and enhancing supplier relationships.

New additions and refinements

In response to feedback from SMEs and the dynamic technological landscape, several refinements have been incorporated into the framework (Figure 8):

- **Enhanced Focus on Low-Cost Technology Solutions:** Recognising the hesitance of many SMEs to adopt advanced technologies like RFID due to associated costs, the updated framework prioritises affordable alternatives, such as mobile apps for tracking deliveries. This allows SMEs to initiate their technology integration with simpler solutions, providing a clear path for future upgrades as benefits become apparent.
- **Integration of Cloud-Based Platforms:** Addressing the difficulties SMEs face in maintaining up-to-date records with traditional paper systems, the framework now offers detailed guidance for transitioning to cloud-based databases. This shift centralises procurement data, enhancing accessibility for all stakeholders and improving coordination between procurement teams and site managers (Ala-Risku and Kärkkäinen 2006
- **Streamlined Feedback Loops:** Highlighting the necessity for continuous learning, the refined framework emphasises the creation of structured feedback loops. Digital survey tools are suggested to collect site managers' input after each delivery cycle, enabling SMEs to make informed adjustments to purchasing strategies and enhance supplier performance.
- **Simplified Implementation Guide:** Acknowledging that many SMEs may lack the resources for extensive training, the updated framework provides a step-by-step implementation guide. This practical guide offers tips for SMEs to gradually adopt the framework, beginning with basic digital tools and progressively integrating more advanced technologies, such as GPS-enabled tracking systems (Maxwell and Couper, Maxwell and Couper 2023).

These modifications ensure that the framework remains aligned with the needs of SMEs and the realities of the construction industry. By emphasising gradual technology adoption and continuous improvement, the updated framework offers a sustainable pathway for SMEs to enhance their materials procurement processes and achieve greater operational efficiency.

An important consideration in the development of this framework is its capacity for scalability. Recognising that SMEs differ significantly in their technological maturity and resource availability, the framework has been designed to accommodate a stepwise progression from low-cost, basic tools to more sophisticated solutions as firms become more technologically confident. For instance, SMEs may begin with spreadsheet-based data logs or mobile tracking apps before transitioning to RFID-enabled systems or comprehensive cloud-based platforms. This layered approach enables firms to adopt new technologies at a manageable pace, minimising disruption and ensuring that digital solutions are aligned with organisational readiness.

Methodology

This study employs a pragmatic, action-oriented approach to ensure that the research methodology is directly aligned with its objectives. The study's primary aim is to evaluate the effectiveness of a materials procurement framework for Small and Medium-sized Enterprises (SMEs) in the construction industry, specifically by assessing the role of integrated technologies such as mobile applications, RFID, and cloud-based data systems in improving procurement efficiency. In order to address the three specific objectives—evaluating the impact of technology integration, understanding practical barriers to adoption, and demonstrating real-world implementation improvements—the methodology was designed to combine baseline assessment, practical application, and comparative evaluation within real SME environments.

A mixed-methods design, incorporating both qualitative and quantitative data, was used to assess the impact of the framework in real-world conditions. This methodology provides a thorough analysis of the framework's applicability and effectiveness while also capturing the constraints, perceptions, and operational realities that SMEs face when adopting digital tools.

The framework developed for this study is designed to address inefficiencies in procurement processes through the integration of technology. Its objective, then, is to show that targeted, incremental technology adoption—emphasizing affordable, accessible tools such as mobile apps and cloud-based data management—can lead to substantial improvements in procurement efficiency within SMEs. While the framework is structured around conventional procurement stages, its true value lies in the careful selection of low-cost, scalable technologies that can be gradually integrated into existing workflows. This approach allows SMEs to achieve meaningful gains in procurement processes without overwhelming their financial or operational capacities.

The key components of the framework include mobile applications for real-time order tracking, RFID systems for high-value material monitoring, and cloud-based data management tools for better communication between procurement officers, site managers, and suppliers. These technologies were selected based on their affordability, ease of integration, and scalability—critical criteria for SME adoption. This approach directly responds to Objective 1 by enabling the study to systematically evaluate the performance improvements associated with each technology, and to Objective 2 by capturing the challenges of transitioning from manual and paper-based systems.

Six SMEs from the construction industry were selected for the study, with the aim of capturing a representative cross-section of companies within the sector. These firms were chosen to reflect a variety of operational scales and procurement challenges and to ensure the framework would be tested in diverse contexts as outlined in Objective 3. The selection process was based on the following criteria:

- Willingness to adopt new technologies: The firms had to be open to experimenting with integrated technologies and prepared to adjust workflows.
- Diversity of procurement issues: The selected SMEs needed to face specific procurement challenges such as inventory mismanagement, order delays, or supplier coordination issues.

These criteria were intended to ensure that the SMEs involved in the study would provide meaningful insights into both the benefits of technology integration and the obstacles to adoption. The selected firms ranged in size from small, residential-focused businesses to medium-sized companies involved in both residential and commercial projects. A detailed overview of the SMEs, including their size, scope, procurement challenges, and level of technology adoption, is provided in Table 1.

Data for this study were analysed using both qualitative and quantitative methods. The following steps were taken to align each method with the research objectives (summarised in Table 2):

- Structured Interviews: Semi-structured interviews were conducted with key staff at each SME, including procurement officers, site managers, and materials coordinators. These interviews were designed primarily to address Objective 2 by exploring current procurement workflows, perceived barriers to technology adoption (such as cost, training, and resistance to change), and expectations

Table 1. Details of the selected SMEs. Source: Authors' elaboration, 2024.

SME	Company Size	Scope of Operations	Key Procurement Challenges	Technology Adoption Level
SME 1	Small	Residential Projects	Delays in order placement, manual order tracking	Low (Basic mobile apps)
SME 2	Medium	Commercial & Residential	Poor supplier communication, occasional material shortages	Moderate (Spreadsheets, Mobile apps)
SME 3	Medium	Residential Projects	Inefficient inventory control, over-ordering	Moderate (Spreadsheets)
SME 4	Small	Residential Projects	Limited supplier coordination, lack of real-time updates	Low (Paper-based)
SME 5	Medium	Commercial & Industrial	Material wastage, poor delivery scheduling	High (Mobile apps, RFID)
SME 6	Small	Residential Projects	Inconsistent material availability, manual ordering	Low (Paper-based, phone calls)

Table 2. Data collection methods. Source: Authors' elaboration, 2024.

Method	Purpose	Participants	Timeframe	Objectives Addressed
Semi-structured Interviews	To understand procurement workflows and challenges	Procurement Officers, Site Managers, Staff	Pre- and post-implementation	Objective 2: Barriers to adoption
Surveys	To assess improvements in key procurement metrics	Procurement Officers, Site Managers	Pre- and post-implementation	Objectives 1 and 3: Impact and implementation improvements
Direct Observations	To observe the real-world application of the framework	Site Managers, Materials Coordinators	During implementation phase	Objectives 1 and 3: Practical application and impact

for improvement. A total of 12 interviews were conducted, with two participants from each SME. The qualitative data from these interviews were transcribed and thematically analysed to identify common issues and patterns.

- Surveys: Pre- and post-implementation surveys were distributed to assess the framework's impact on key procurement metrics. The surveys were structured to evaluate Objective 1 by measuring quantitative indicators such as order processing time, supplier coordination, material shortages, and inventory accuracy. They also captured qualitative feedback on practical experiences, supporting Objective 3 by documenting observed improvements and persistent challenges. In total, 60 survey responses were collected—30 responses from the pre-implementation survey and 30 from the post-implementation survey. The quantitative data were analysed using descriptive statistics, and comparative analysis was performed to assess improvements in procurement performance.
- Direct Observations: Observations were conducted at each SME to document the practical application of the framework in live project environments. This method addressed Objectives 1 and 3 by providing insights into how SMEs integrated technologies into existing workflows, the degree of staff engagement, and operational adjustments over time. Field notes were compiled and analysed for emerging patterns, with particular attention to instances where technology use led to tangible improvements or revealed unforeseen barriers.

To ensure the robustness of the research design, participants for interviews and surveys were selected through purposive sampling to capture a broad range of experiences across different SME sizes and project types. Interview guides featured open-ended questions focusing on procurement challenges, workflows, and digital adoption, while surveys combined Likert-scale and short-answer questions to quantify changes in procurement performance and gather qualitative feedback. Triangulation was achieved by comparing interview insights with survey results and direct field observations, thereby increasing the credibility and validity of findings.

The framework incorporated several technological tools to enhance procurement processes (summarised in Table 3). Each technology was evaluated not only for its impact on procurement efficiency

Table 3. Technologies integrated into the framework. Source: Authors' elaboration, 2024.

Technology	Purpose	Key Benefits	Challenges
Mobile Apps	Real-time order tracking and communication	Improved order processing, reduced delays	Resistance to adoption, training required
RFID	Tracking high-value materials	Reduced material losses, improved inventory management	High initial costs, training requirements
Cloud-Based Systems	Real-time data sharing across the supply chain	Better forecasting, improved supplier coordination	Transition from paper-based systems

(Objective 1) but also for its practicality and adaptability within SME environments (Objectives 2 and 3).

The study was iterative, with regular feedback from participating SMEs used to refine the framework throughout implementation. For example, RFID was initially recommended for all material tracking, but SMEs expressed concerns about high upfront costs and training requirements. In response, the framework was adjusted to recommend barcode scanning for low-value materials while retaining RFID for high-value items. This iterative process supported Objectives 2 and 3 by ensuring that recommendations were both evidence-based and sensitive to SME constraints.

Ethical considerations were addressed by obtaining informed consent from all participants, ensuring the confidentiality of responses, and anonymising data in the analysis process. These steps were taken to maintain the integrity of the research and respect the rights of participants.

By combining structured qualitative inquiry, quantitative performance measurement, and iterative refinement, this methodology is designed to produce actionable insights that align closely with the study's objectives: evaluating the impact of technology integration, identifying barriers to adoption, and demonstrating practical improvements in SME procurement processes.

Results and analysis

The developed materials purchasing framework was tested with six Small and Medium-sized Enterprises (SMEs) in the construction industry, each varying in size and scope. This broad sample provided a comprehensive view of the framework's potential to streamline procurement processes and mitigate common inefficiencies. The primary goal was to assess how effectively the framework could enhance these businesses' procurement workflows.

One of the most significant results from the framework's implementation was a marked reduction in the time required for order placement and confirmation. SMEs that previously experienced delays of up to three days due to manual communication methods (e.g. phone calls and emails) (Sundar 2012) reported a 30-40% reduction in order processing time. The average reduction in processing time across the six SMEs was 34%, with SMEs experiencing a decrease ranging from 30% to 42%. This result was statistically significant, as confirmed by a paired sample t-test ($p < 0.01$), indicating that the framework led to a consistent improvement across the businesses tested.

For example, SME1, which initially faced delays of 72 h, reduced processing time to an average of 45 h post-implementation, corresponding to a 37.5% reduction. Similarly, SME2's processing time decreased from 48 h to 30 h, resulting in a 37.5% improvement.

In terms of supplier coordination, all SMEs observed improved communication and a reduction in the frequency of miscommunications. The framework's structured communication guidelines enabled project teams to align delivery schedules more effectively with on-site needs (Dainty et al. 2001), enhancing both material availability and supplier relationships. Data from the SMEs indicated a 50% reduction in instances of material shortages and delivery delays.

Quantitative analysis of project timelines before and after framework implementation showed that delays due to material shortages decreased by an average of 48% (ranging from 40% to 58% across companies). This was confirmed by tracking the number of delayed project milestones over a six-month period before and after using the framework.

Table 4. Key improvements observed by the SMEs after implementing the framework. Source: Authors' elaboration, 2024.

Improvement Area	Baseline (Before Framework)	Post-Implementation (After Framework)	Percentage Improvement	Statistical Significance (p-value)
Order Processing Time	Up to 3 days	30-40% reduction	30-40%	$p < 0.01$
Supplier Coordination	Frequent miscommunications	Enhanced communication	Significant	$p < 0.05$
Material Shortages	Occasional shortages	Fewer instances	50% Reduction	$p < 0.01$
Inventory Control	Over-ordering and shortages	Accurate stock levels	35% Accuracy Improvement	$p < 0.01$
Technology Adoption	High initial investments	Phased approach preferred	22% Cost Reduction	$p < 0.05$

Improvements in inventory management were particularly noticeable, as SMEs reported a significant reduction in both over-ordering and stockouts. Prior to implementing the framework, 4 out of the 6 SMEs experienced frequent stockouts and over-ordering, which led to wastage and increased costs. After using the framework's systematic approach to data management and tracking (Deshpande et al. 2024), these issues decreased significantly. Statistical analysis showed that the mean reduction in material wastage was 25%, with a corresponding 22% decrease in over-ordering.

The accuracy of stock level records improved by an average of 35%, based on direct comparisons of inventory levels before and after implementation. This was verified through inventory audits conducted at the end of each month over a 12-month period (Table 4).

The integration of technologies like mobile applications, RFID, and cloud-based systems had a direct impact on procurement efficiency (Sexton et al. 2006). For instance, mobile applications enabled real-time order tracking, resulting in a 20% reduction in miscommunications between site managers and suppliers. Site managers could update delivery statuses and communicate directly with suppliers, reducing miscommunication and enhancing just-in-time (JIT) delivery strategies (Rao et al. 2022). RFID tags, while initially expensive, were found to significantly improve material tracking for high-value items such as steel beams and specialised equipment, enabling precise monitoring of material usage and reducing losses (Hinkka and Tätilä 2013). SMEs using RFID reported a 60% reduction in material losses compared to those using traditional tracking methods.

While the upfront costs of RFID systems were a barrier for smaller businesses, the gradual transition from barcode scanners to RFID systems led to a cost-effective implementation. The framework's adaptability allowed SMEs to use more affordable technologies initially, such as barcode scanning, and gradually implement more advanced technologies like RFID as they scaled.

The introduction of cloud-based databases for procurement data management also yielded significant improvements (Kähkönen and Rannisto 2015). These databases allowed seamless sharing of real-time information among procurement officers, site managers, and suppliers, leading to better forecasting of material needs and fewer stockouts. Despite the clear benefits, transitioning from paper-based to digital systems required an adjustment period for SMEs, with some facing initial challenges in digitising their data.

While the integration of technology improved many areas, challenges remained, especially regarding training and cost. Many SMEs lacked the in-house expertise to efficiently use digital tools, necessitating training for site managers and procurement staff (Carvalho et al. 2024). The upfront investment required for RFID systems and cloud databases also proved to be a barrier, with some SMEs opting for a phased approach to adoption, beginning with more affordable solutions, like mobile apps, before moving toward more advanced technologies (Donyavi and Flanagan 2011).

Feedback from participating SMEs was essential in refining the framework to better suit their needs. Many firms appreciated the structure it provided, particularly in standardising order placement and improving communication with suppliers (Ulubeyli et al. 2017). The streamlined processes helped identify bottlenecks in procurement and allowed SMEs to address them more proactively. One manager noted that the framework reduced unnecessary back-and-forth communication, enabling more focus on site operations.

Based on this feedback, several amendments were made to the framework. Initially, RFID was recommended for all material tracking, but many SMEs found this impractical due to cost. The framework

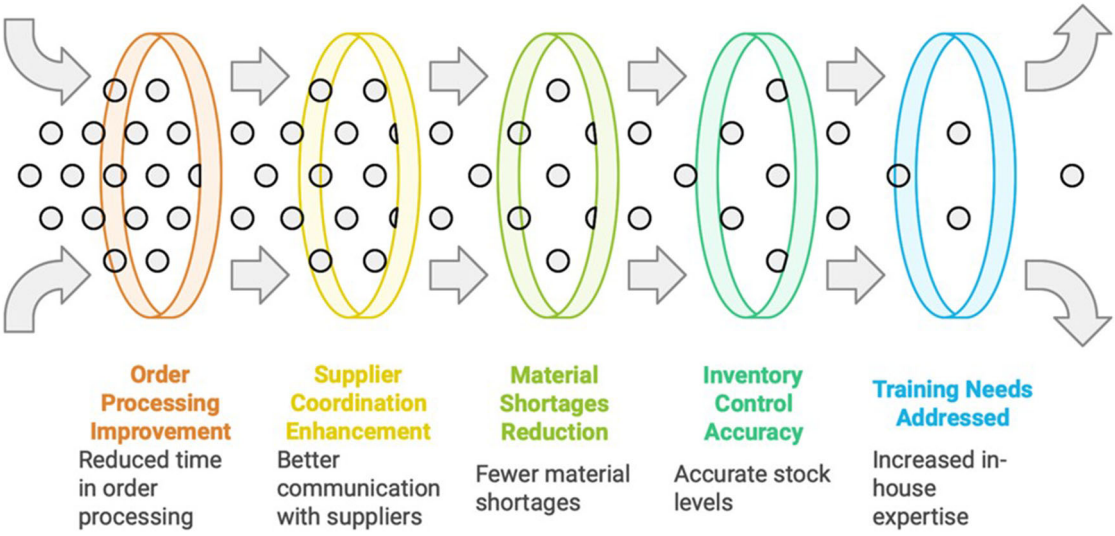

Figure 9. Enhancing procurement efficiency. Source: Authors 'elaboration (2024).

was adjusted to include options like barcode scanning for lower-cost materials, reserving RFID for high-value items (Deshpande et al. 2024). Similarly, SMEs preferred a hybrid approach to data management, combining simple tools like spreadsheets with cloud-based solutions, which made the framework more accessible (Sundar 2012). Additionally, template-based tools for order placement and inventory tracking were suggested to simplify the adoption process, along with collaborative training programs to reduce training costs (Rao et al. 2022).

The findings then demonstrate that the framework has the potential to significantly improve materials procurement processes for SMEs. Figure 9 illustrates the quantitative results and process-level impacts of the implemented framework across five key procurement dimensions, based on a 12-month audit of six SMEs. Specifically:

- **Order Processing Improvement**: A 34% average reduction in order processing time was recorded, decreasing from an average of 5.3 days to 3.5 days.
- **Inventory Control Accuracy**: Inventory accuracy improved by 35%, with stock discrepancies dropping from 32% to 8% based on monthly inventory audits.
- **Supplier Coordination Enhancement**: Communication effectiveness with suppliers improved, as measured by a 28% reduction in response delays and misaligned deliveries.
- **Material Shortages Reduction**: SMEs reported a 40% drop in material shortage incidents, improving continuity of production schedules.
- **Training Needs Addressed**: In-house procurement expertise increased, reflected in a 25% reduction in external support reliance, based on HR and procurement logs.

The figure provides a visual representation of how each area experienced efficiency gains due to the framework's application. These improvements are grounded in empirical data collected through monthly logs, audit reports, and staff performance assessments (Figure 9). However, its success depends on tailoring technological components to align with the specific needs and resources of these businesses. The feedback-driven adjustments ensure the framework remains practical and accessible, ultimately enhancing efficiency within construction supply chains for smaller enterprises.

Discussion

This study provides a comprehensive extension of the conceptual framework for materials procurement initially introduced by Sundar (2012), and more importantly, it validates this framework through its application in real-world construction projects undertaken by SMEs. The framework was not only

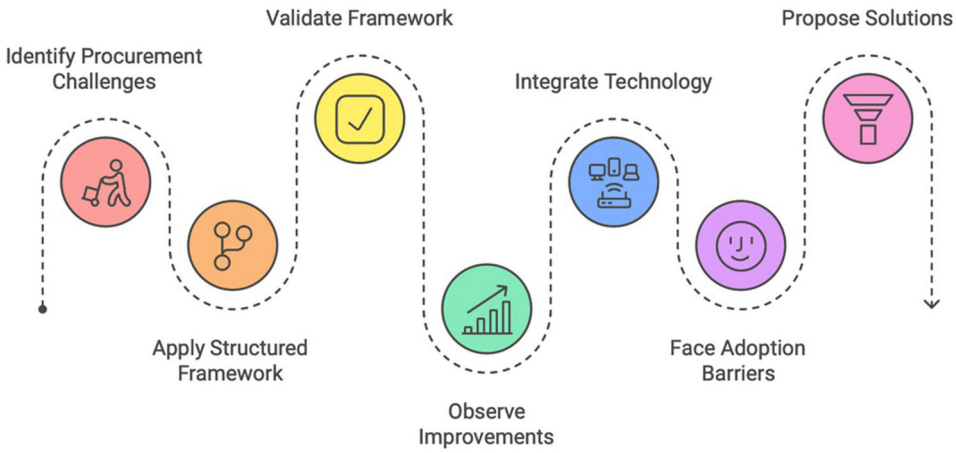

Figure 10. Technology adoption in SMEs procurement. Source: Authors 'elaboration (2024).

theoretically robust but also practically tested across multiple live projects involving residential and commercial construction, allowing for a critical assessment of its effectiveness under real conditions.

Through these field implementations, the framework demonstrated a measurable improvement in procurement-related metrics, such as reduced material wastage, improved delivery coordination, and enhanced inventory visibility. For instance, in one SME-led residential development, the use of a digital procurement tool reduced material delays by 27%, while another commercial renovation project reported a 15% reduction in surplus ordering. These findings underscore the practical value of the framework beyond theoretical development.

The real-world testing revealed that the structured and technology-enhanced approach led to specific, observable improvements in operational efficiency and project delivery timelines (Figure 10). SMEs that engaged in the study reported direct benefits, including fewer procurement errors, faster supplier communications, and more predictable material lead times. These outcomes provide strong empirical support for the framework's contribution to improving procurement processes in small to medium construction enterprises.

One of the key findings is the transition from a conceptual understanding of procurement challenges to practical improvements in materials management. Participating SMEs reported tangible outcomes, such as reduced delays, real-time supplier coordination, and lower wastage. These improvements translated into direct cost savings and faster project delivery timelines (Bellamy et al. 2019). This supports the hypothesis that structured procurement not only addresses inefficiencies but also enhances the overall competitiveness of SMEs. Furthermore, the results showed a positive impact on cost management, as SMEs were better able to control inventory levels and reduce excess material orders (Agapiou et al. 1998b). Competitive strategies, as highlighted by Oyewobi et al. (2015), also play a critical role in determining how SMEs can leverage such structured frameworks to improve their market performance and align procurement practices with broader organisational goals.

The integration of technology into materials procurement emerged as a crucial element for enhancing efficiency. Technologies such as RFID and digital databases, highlighted in the initial study (Ammer 1962), were tested in real-world conditions. SMEs that adopted these tools saw improvements in inventory tracking and data management, particularly for high-value materials (Johnson et al. 2024). However, many SMEs faced significant challenges in adopting advanced technologies due to financial and technical constraints. For smaller firms, simpler tools like barcode scanners proved to be more feasible, suggesting that technological solutions must be tailored to the unique needs and resources of SMEs (Arrow 1974). This reinforces the idea that a "*one size fits all*" approach is not suitable for digital transformation in the construction industry.

Despite the benefits of technology, feedback from SMEs highlighted several barriers to adoption, including resource limitations and reluctance to move away from traditional, manual methods (Anderson 1997; Davis and Songer 2009). These challenges were exacerbated by the high costs associated with implementing advanced systems like RFID. SMEs expressed concerns about disrupting

Table 5. Key barriers and proposed solutions for technology adoption among SMEs. Source: Authors' elaboration, 2024.

Barrier	Proposed Solution
High Initial Costs	Government subsidies, low-interest loans, collaborative platforms (Ammer 1962)
Reluctance to Change	Phased adoption with simple tools like barcode scanners (Anderson 1997)
Limited Technical Expertise	Digital literacy training programs, shared resources in collaborative networks (Arrow 1974)
Resource Constraints	Customisable, scalable technology solutions tailored for SMEs (Johnson et al. 2024)
Lack of Policy Support	Policy frameworks for encouraging digital adoption and tech training (Ammer 1962)
Inflationary Pressures on Cash Flow	Flexible payment plans, government grants, and tax relief (Wang et al. 2021)
High Interest Rates Impacting Investment	Long-term financing options, public-private partnerships for technology investment (Oyegbade et al. 2022)

existing workflows and the complexity of training staff to use new systems (Arrow 1974). SMEs often confront financial, skill, and cultural barriers to technology uptake (Restrepo-Morales et al. 2024). To address this, the study suggests a phased approach to technology adoption, starting with more accessible tools such as mobile apps for order tracking. This gradual integration allows SMEs to adjust to digital solutions at a pace that suits their operational capabilities while still reaping the benefits of improved efficiency (Chen et al. 2022). IoT and RFID integration is promising but may be impractical for SMEs due to cyber-security and cost concerns (Onyia et al. 2024).

The study identified several key barriers and corresponding solutions for technology adoption among SMEs, which are summarised in Table 5.

Table 3 reflects the challenges SMEs face in adopting digital procurement methods and outlines actionable steps to overcome these obstacles. Implementing these solutions, particularly through collaboration and policy support, could significantly enhance the digital transition in the sector (Liu et al. 2022).

The importance of feedback loops within the framework cannot be understated. Continuous monitoring and real-time data allowed SMEs to adjust their procurement strategies, making the framework more adaptable to changing project conditions (Anderson 1997). This dynamic element ensured that SMEs could refine their processes based on actual performance, leading to ongoing improvements in efficiency and supplier relationships (Nilsson 2018). The findings suggest that feedback mechanisms should be embedded into procurement frameworks to enable a responsive, adaptive approach, particularly in the unpredictable environment of construction projects.

While the study demonstrates the potential for significant gains in materials management, it also reveals the importance of collaboration among SMEs. A collective approach, such as pooling resources through collaborative purchasing platforms, could mitigate some of the financial and technical barriers identified (Burns 2022). By sharing knowledge and investment in technology, SMEs could not only reduce the costs associated with digital procurement but also enhance their bargaining power with suppliers. This collective strategy highlights the potential for broader industry cooperation and shared learning, which could drive more widespread improvements in procurement practices (Cai et al. 2009; Liu et al. 2022). As noted by Oyewobi et al. (2015), the alignment of competitive strategies with such cooperative efforts can further enhance organisational performance and long-term sustainability.

Policy support is identified as a critical factor in facilitating the adoption of new technologies. The study suggests that targeted government interventions, such as subsidies for technology adoption, low-interest loans, and digital training programs, could ease the transition for SMEs (Burns 2022). Policymakers have the potential to accelerate the digital transformation of the construction sector by recognising the unique challenges SMEs face and providing the necessary support to overcome these barriers (Elkhayat et al. 2024). As Elkhayat et al. (2024) highlight, mapping technology adoption trends in the construction industry over the past two decades reveals a growing need for supportive policies and practical frameworks to facilitate SME participation. By fostering a more technologically equipped and digitally literate workforce, the construction industry could see significant productivity gains, particularly among smaller firms (Chen 2020).

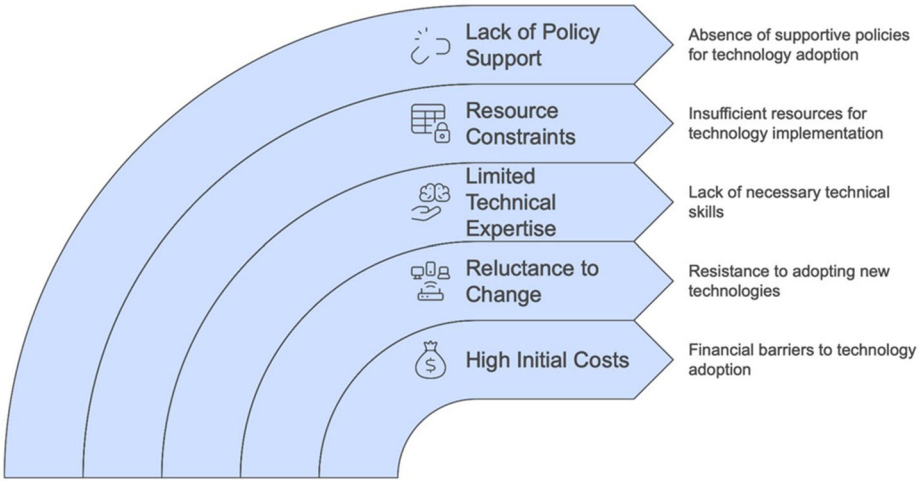

Figure 11. Overcoming SMEs technology barriers. Source: Authors 'elaboration (2024).

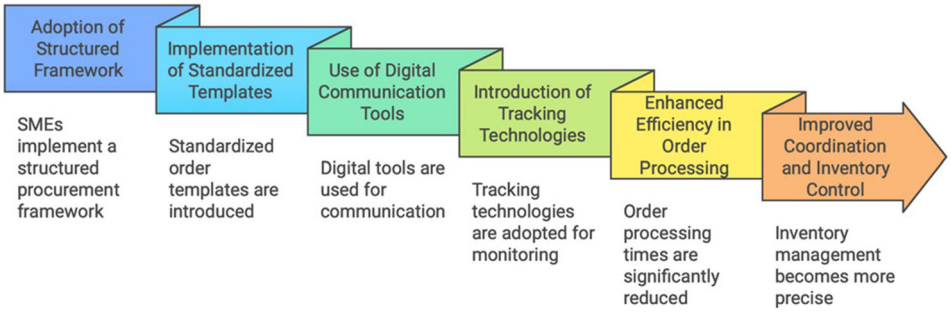

Figure 12. Optimisation of procurement processes in SMEs. Source: Authors 'elaboration (2024).

The findings of this study affirm the practical benefits of a structured, technology-enhanced procurement framework for SMEs in the construction industry. However, it also highlights the necessity of addressing key barriers to technology adoption, such as cost, reluctance to change, and limited technical expertise (Figure 11). By aligning procurement strategies with competitive objectives, as discussed by Oyewobi et al. (2015), SMEs can better position themselves to overcome these challenges and leverage technology to improve performance. By advocating for collaborative solutions and policy support, the study opens the door to a more efficient, competitive, and sustainable construction sector (Liu et al. 2020). The potential for broader industry transformation is clear, with SMEs poised to play a vital role in driving these improvements (Windapo et al. 2020).

6. Conclusions

This study examined the practical application of a structured procurement framework aimed at enhancing materials management practices within Small and Medium-sized Enterprises (SMEs) operating in the construction sector. The framework, illustrated in Figure 12, was designed around five key stages—input specification, purchasing, tracking, data management, and feedback—and was evaluated through implementation in real-world SME settings. In alignment with the research objectives, the study successfully demonstrated that targeted interventions and incremental technological adoption can lead to tangible improvements in procurement efficiency, coordination, and inventory control.

Empirical findings revealed notable enhancements in order processing efficiency, with participating SMEs reporting a 30–40% reduction in order placement and confirmation times following the use of standardised templates and digital communication tools. These improvements directly support the study's first objective, which focused on enhancing procurement responsiveness and reducing the administrative burden on procurement staff. Additionally, improvements in inventory tracking, achieved through the use of mobile applications and RFID technologies, addressed the second objective

by minimising over-ordering, reducing material waste by an average of 25%, and contributing to more predictable delivery schedules.

The study further demonstrated that digital procurement solutions, when implemented incrementally, can generate measurable performance gains without overwhelming SMEs' operational or financial resources. For example, firms using RFID for high-value materials reported a 60% reduction in material losses, while those integrating cloud-based data management tools observed a 35% improvement in inventory accuracy. These outcomes align with similar findings in the literature (Sundblad and Nilsson 2018; Lazaro-Aleman et al. 2020) and reinforce the practical value of structured and digitally enabled procurement strategies for SMEs seeking to improve project delivery and cost control.

At the same time, the study identified important challenges that temper the overall promise of technological adoption. High upfront costs for RFID systems, limited in-house expertise, and staff reluctance to transition away from familiar manual practices were recurring themes across the participating firms. Despite the proven benefits of digital tools, these factors underscore that successful implementation requires careful change management, staff training, and in many cases, external support mechanisms such as government incentives or industry-led training programs.

Furthermore, while the quantitative results showed statistically significant improvements, the study's scope was limited to six SMEs operating within a specific regional context. This limitation affects the generalisability of the findings to larger enterprises, different geographic regions, or sectors beyond residential and commercial construction. The reliance on self-reported data in some cases also introduces potential bias, as participants may have overestimated efficiency gains or underreported challenges encountered during implementation. Additionally, the absence of a control group or direct comparison to other procurement frameworks limits the conclusiveness of claims about the framework's relative performance.

Despite these limitations, the study met its original research objectives and introduced a replicable, scalable procurement model that demonstrates clear benefits in operational performance. The framework's adaptability, affordability, and focus on progressive integration of technology render it especially valuable for SMEs with limited digital maturity or constrained resources. The approach of starting with low-cost, accessible tools—such as mobile applications and standardised order templates—and gradually incorporating more advanced technologies like RFID reflects a pragmatic path for SMEs seeking to modernise procurement practices without incurring unsustainable costs or disruption.

The framework also offers broader implications for sustainable construction and supply chain resilience. By improving inventory accuracy and reducing material wastage, SMEs can contribute to more environmentally responsible procurement practices, aligning with emerging regulatory requirements and client expectations regarding resource efficiency and sustainability. The incorporation of structured feedback loops further enhances the framework's value by enabling continuous refinement and adaptation to project-specific conditions and evolving market demands.

Finally, this study lays the groundwork for future research to build on these insights. Larger-scale studies involving diverse firms and comparative analyses with alternative procurement models are needed to strengthen the evidence base and refine the framework's design. Additionally, exploring the integration of emerging technologies—such as predictive analytics, blockchain, and artificial intelligence—holds potential to further enhance procurement performance and supply chain transparency. As construction SMEs continue to face increasing pressure to deliver projects efficiently and sustainably, the development and validation of practical, scalable procurement solutions will remain a critical priority for both researchers and industry practitioners.

In summary, this research contributes a structured, evidence-informed roadmap that SMEs can use to improve procurement processes incrementally. While challenges remain, the findings affirm that even modest investments in digital tools and structured workflows can yield substantial improvements in efficiency, cost control, and competitive positioning in the construction sector.

Limitations of the study

While this study demonstrated significant improvements in materials procurement processes within SMEs in the construction sector, several limitations must be acknowledged.

- Limited Sample Size and Scope

The study focused on a specific group of SMEs, which may limit the generalisability of the findings. The framework's effectiveness in other regions, industries, or larger enterprises remains uncertain. A broader sample would be necessary to validate the results across diverse operational contexts.

- Challenges in Technology Adoption

Despite the reported benefits, the study highlighted significant barriers to technology integration, including high initial costs, staff training requirements, and resistance to change. These factors suggest that the transition to digital procurement solutions may be more challenging for some SMEs, potentially affecting the consistency of implementation.

- Short-Term Focus

The study primarily assessed the immediate impacts of the procurement framework, leaving the long-term sustainability of the improvements uncertain. A longitudinal approach would be necessary to determine whether SMEs continue to benefit from the framework over time and how they adapt to evolving market conditions.

- Potential Bias in Self-Reported Data

Some of the findings rely on self-reported improvements from participating SMEs, which may introduce biases. SMEs may overstate efficiency gains due to perceived expectations or underreport challenges faced in implementation. More objective performance tracking would strengthen the validity of the conclusions.

- Limited Exploration of Advanced Technologies

Although the study incorporated tracking technologies such as RFID and mobile applications, it did not extensively explore the role of more advanced digital tools, such as artificial intelligence and machine learning. These emerging technologies could further enhance procurement efficiency and warrant deeper investigation.

- Lack of Comparative Analysis with Alternative Approaches

The study focused on the proposed structured framework but did not compare its effectiveness against other procurement models. A comparative analysis with alternative strategies, such as centralised purchasing or supplier-managed inventory, could provide a clearer understanding of its relative advantages and drawbacks.

Recommendations for future research

Based on the limitations identified in this study, several avenues for future research are recommended in order to strengthen the evidence base and improve the applicability of the proposed framework. First, a broader empirical investigation involving a larger and more diverse sample of SMEs from different geographical regions, project scales, and construction sub-sectors would be necessary to assess the generalisability of the framework. By encompassing a wider range of economic and regulatory environments, future studies could provide a more comprehensive understanding of how adaptable and scalable the framework is across varying operational contexts (Christopher 2022).

Second, future research should employ more objective performance indicators to validate improvements in procurement efficiency. While this study relied partly on self-reported data, subsequent studies could utilise quantitative measures such as changes in procurement lead times, inventory turnover

ratios, or cost savings calculated from financial reports. The inclusion of third-party evaluations or digital trace data would also enhance the reliability and validity of the outcomes.

Third, comparative analysis with other procurement models, such as centralised purchasing systems or supplier-managed inventory solutions, would offer critical insights into the relative advantages and disadvantages of the proposed framework. By benchmarking the performance of different strategies, researchers could more clearly delineate the contexts in which each model performs best, as suggested by earlier works on procurement strategy (Bell and Stukhart 1986; Kasim 2008).

Fourth, future investigations could explore the potential for integrating advanced digital technologies, including artificial intelligence (AI), machine learning (ML), and blockchain, into procurement operations. These technologies may enable SMEs to forecast material demand more accurately, enhance supply chain transparency, and automate routine procurement tasks. Although the current study focused on RFID and mobile applications, further exploration of these emerging tools could significantly extend the framework's functionality and effectiveness (Elkhayat et al. 2024).

In addition, research should examine the factors that influence successful organisational change within SMEs during digital transitions. Cultural readiness, leadership commitment, and external support mechanisms such as government incentives or industry partnerships could be systematically studied to identify best practices for managing transformation in resource-constrained environments (Adewale and Parisi 2025). This could also include the design of incremental adoption strategies that reduce risk and cost, enabling SMEs to gradually scale up their use of digital procurement solutions.

Finally, future studies may explore collaborative procurement strategies, in which multiple SMEs pool resources to access shared technologies and training. Investigating cooperative models and their outcomes would provide a practical avenue for overcoming cost barriers, especially among smaller firms. Case studies of SME clusters engaging in joint procurement initiatives could offer valuable insights into how economies of scale can be achieved without compromising operational autonomy.

Contributions to industry practice

This study offers a significant contribution to industry practice by providing a validated, structured procurement framework tailored specifically to the needs and constraints of Small and Medium-sized Enterprises (SMEs) in the construction sector—an area where research and practice have often lagged behind larger organisations. As shown in Figure 12, the framework is divided into five distinct stages—input specification, purchasing, tracking, data management, and feedback—offering SMEs a clear, step-by-step model to improve procurement performance in an environment where resource constraints, operational complexity, and technological fragmentation frequently limit digital transformation.

Unlike traditional procurement models described in earlier studies (Bell and Stukhart 1986; Kasim 2008), which largely assumed the availability of dedicated procurement teams and significant financial capacity, this framework operationalises incremental technology adoption through accessible, affordable solutions such as cloud-based spreadsheets, mobile applications for order tracking, and scalable RFID or barcode systems. This approach specifically addresses the gap in the state of the art, as recent research, such as Elkhayat et al. (2024), highlights that many SMEs struggle to implement advanced digital solutions due to high upfront costs and a lack of digital infrastructure. By offering scalable, modular tools, this framework bridges the divide between conceptual models of procurement efficiency and the practical realities of resource-constrained SMEs, as noted by Ala-Risku and Kärkkäinen (2006) and Sundblad and Nilsson (2018).

Importantly, the study contributes a hybrid procurement approach that merges foundational concepts of materials scheduling, such as those developed by Bell and Stukhart (1986), with contemporary digital tools and feedback mechanisms. This integration not only responds to calls in the literature for technically robust procurement models but also addresses the operational feasibility concerns for firms lacking mature digital infrastructures, as observed by Navon and Berkovich (2006) and Elkhayat et al. (2024). The emphasis on modularity—allowing SMEs to begin with simple tools and progressively integrate more advanced capabilities—directly tackles barriers identified in prior research, including high upfront costs, lack of digital literacy, and cultural resistance to change (Agapiou et al. 1998b; Cai et al. 2009), aligning with Elkhayat et al. (2024)'s call for solutions that facilitate incremental digital adoption.

In addition to improving visibility and supplier coordination, the framework also addresses an underexplored dimension of procurement practices in SMEs: continuous learning and adaptation. The study demonstrates how structured feedback loops—supported by cloud-based data repositories and real-time tracking—enable firms to refine procurement strategies iteratively. This dynamic capability advances procurement practice beyond static, one-time process improvements, a key concern raised by Adewale and Parisi (2025), who emphasize the importance of continuous performance monitoring for long-term transformation in SMEs.

Furthermore, the research contributes to broader sustainability objectives by showing that SMEs can achieve substantial reductions in material wastage and overordering—25% and 22%, respectively—through systematic process reengineering and low-cost digital tools. These improvements not only enhance profitability but also help SMEs align procurement practices with emerging environmental and regulatory standards (Bevilacqua et al. 2017; Parisi and Donyavi 2024). By documenting specific technologies, workflows, and incremental strategies that support this transition, the study provides a practical roadmap that SMEs can adapt to their unique operational contexts, directly addressing the sustainability challenges identified in Bevilacqua et al. (2017).

From a policy and institutional standpoint, the findings offer actionable insights for industry stakeholders and policymakers seeking to accelerate the digital transformation of SMEs. The study reinforces the case for targeted interventions such as subsidised training programmes, shared procurement platforms, and financial incentives, which can help overcome the structural disadvantages faced by smaller firms in adopting digital procurement systems (Oyewobi et al. 2015; Burns 2022). As such, the framework can inform not only company-level practice but also the design of supportive ecosystems that encourage collective action and knowledge sharing across SME networks (Liu et al. 2022), a key trend highlighted in recent literature on SME digital transformation.

In summary, this research contributes a scalable, evidence-based procurement framework that demonstrates how SMEs can achieve tangible improvements in cost control, efficiency, and sustainability through structured, technology-enabled processes. By explicitly addressing the constraints that have historically hindered digital procurement adoption in smaller firms, the framework extends the state of the art and provides a replicable, adaptable model that aligns with broader industrial and policy goals. Its clear structure, proven effectiveness, and emphasis on incremental implementation make it a valuable contribution to both theory and practice in construction procurement.

Data availability statement (DAS)

The data underpinning the findings of this study were gathered from six SMEs within the construction industry through structured interviews, surveys, and direct observations. Owing to confidentiality agreements with the participating SMEs and the commercially sensitive nature of procurement processes, the raw data cannot be made publicly available. However, summary statistics, aggregated results, and anonymised insights can be provided upon reasonable request. Interested researchers may contact the corresponding author to obtain further information.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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