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ERP Systems and Cost Control in the Construction Industry: A Conceptual Analysis of Material Flow Management

Abstract

Objective: Effective stock management and material flow control are essential for optimizing inventory levels and improving project performance in the construction sector, where decentralised job sites, variable material consumption, fragmented supply chains and strict budget constraints create distinctive operational challenges. Inadequate visibility of material flows often results in waste, emergency procurement, cost overruns and project delays. This paper examines how integrated management practices, supported by Enterprise Resource Planning (ERP) systems and complementary digital technologies such as Building Information Modeling (BIM), can enhance cost control, budget monitoring and visibility across material flows.

Methodology: Using a qualitative, exploratory, and descriptive approach, the study conducts a narrative/conceptual review of the literature with thematic content analysis and compares construction practices with those of more standardized sectors, such as retail and manufacturing.

Findings: The analysis highlights the specific inventory and logistics challenges faced by construction organisations and explores how digital integration can support more effective decision-making and resource coordination. Based on the findings, a conceptual framework is proposed linking ERP–BIM integration, material flow visibility, operational performance and cost control outcomes.

Value Added: The study contributes to the literature by synthesizing fragmented knowledge on construction logistics, inventory management and digital technologies into a unified conceptual perspective. From a managerial standpoint, the findings emphasise the importance of investing in integrated digital systems and real-time information sharing to improve inventory accuracy, reduce material losses and strengthen budget governance.

Recommendations: The paper also identifies opportunities for future empirical research, particularly through quantitative studies and multiple case analyses assessing the impact of digital integration on construction project performance.

Key words: inventory management, cost avoidance, cost control, budget control, construction logistics, ERP, BIM

JEL codes: M11, M41, O33, L74

Introduction

Inventory management has become a strategic organisational function, playing a central role in balancing supply and demand, controlling costs and increasing operational efficiency. In a highly competitive and dynamic environment, effective inventory management is crucial to business sustainability and profitability. However, the challenges associated with inventory management vary significantly across industries and are particularly critical in the construction sector.

Construction presents unique operational characteristics that hinder the application of traditional inventory control models. Projects are decentralised, raw material prices are volatile, deadlines are strict and construction processes are highly customized. These features make material management more complex and error-prone. Ineffective inventory control may lead to waste, delays, unnecessary expenditures and even project interruptions.

In contrast, sectors such as retail and manufacturing operate with more predictable demand patterns and continuous production flows, allowing for more structured planning. While these sectors also face logistical challenges, their centralised and stable environments facilitate greater automation and the use of advanced tracking technologies.

This study aims to examine how ERP and BIM integration can improve material flow visibility and cost control in the construction sector.

Based on these considerations, the following research questions were formulated:

RQ1: *What inventory and material flow challenges distinguish construction from more standardized sectors?*

RQ2: *How can ERP and BIM integration improve material flow visibility and cost control?*

RQ3: *What managerial implications emerge from the adoption of integrated digital systems in construction projects?*

The relevance of this topic lies in the growing need for construction companies to adopt modern and integrated material control practices, not only to reduce waste but also to reinforce competitiveness and project sustainability. This research provides a critical reflection on how material logistics can evolve through technological tools and management models adapted to the sector's specificities.

Theoretical Framework

Fundamental Concepts of Inventory and Logistics

Inventory management is a core element of business logistics, ensuring a balance between product availability and storage costs. According to Ballou (2006), inventory acts as a buffer between different stages of production and distribution within the supply chain. Effective management reduces losses, minimizes operational costs and ensures process continuity.

Inventory categories include raw materials, work-in-progress items and finished goods. Management requires decisions regarding order quantities, replenishment schedules and control models such as Just-in-Time (JIT), reorder points and continuous replenishment systems (Slack et al., 2015). Digital technologies are crucial to mitigate supply chain fragmentation (Papadonikolaki & Wamelink, 2017). In sectors with predictable demand – like retail – these models are especially efficient.

However, the construction sector faces distinct challenges due to the dynamic and variable nature of its activities. Projects are executed in temporary, site-based environments with unique physical, organisational and operational conditions, making standardisation difficult and increasing uncertainty and variability in project execution (Ballard & Howell, 2003). A major challenge in construction logistics is the decentralised storage of materials. Deliveries are typically made directly to construction sites, where storage space is often limited and site conditions may expose materials to damage, deterioration or theft. Delays in deliveries or unexpected variations in material consumption can disrupt project schedules, resulting in emergency procurement and increased project costs (Johnston, 2016).

Recent studies emphasise the importance of integrating technologies such as Building Information Modeling (BIM) and Enterprise Resource Planning (ERP) to improve inventory visibility, accuracy and decision-making (Luz et al., 2020).

Budget Control and Material Flow

Target Costing Management (TCM) aligns cost planning with organisational strategy and market expectations (Cooper & Slagmulder, 1999). It emphasizes early-stage decision-making during product development, where the majority of life-cycle costs are defined (Yasukata et al., 2013). Functional analysis plays a pivotal role in enhancing competitive advantage (Mouritsen et al., 2001). TCM requires cross-functional collaboration involving planning, engineering, procurement, finance and production teams. Designers rely on accurate information regarding customer needs, material availability and production capabilities (Ansari & Bell, 1997). Perčević et al. (2015) highlight eight key characteristics of TCM: market-based target prices, strategic profit margins, early cost definition, cost decomposition, cross-functional teamwork, detailed cost data, systematic cost comparison and strict adherence to target cost limits. Contingency theory explains variations in TCM adoption across non-Japanese firms, as management practices must be adapted to contextual conditions (Carr & Ng, 1995; Drury, 2006).

Value Stream Mapping (VSM), proposed by Rother and Shook (2003), provides a visual representation of material and information flows across processes. It distinguishes value-adding from non-value-adding activities, supporting waste reduction and continuous improvement. Once the strategic direction is set, implementation is carried out by cross-functional teams. This stage is pivotal and should include professionals from diverse areas such as planning, marketing, engineering, finance, procurement and production. For instance, product designers require comprehensive information on customer preferences, manufacturing capabilities and material availability. Based on these data, they determine both the type of product to be developed and how it will be produced (Ansari & Bell, 1997; Yasukata et al., 2013).

Research on non-Japanese firms reveals some variations in how TCM is applied (Carr & Ng, 1995; Ellram, 2006; Talha & Raja, 2010). According to contingency theory, such differences are to be expected, as any new management accounting system must be tailored to fit the specific context in which it is implemented (Carenzo & Turolla, 2010; Drury, 2006). According to Rother and Shook (2003), the Value Stream Mapping (VSM) methodology involves creating a visual map of the production system that distinguishes between activities that add value and those that do not. This tool is used to analyse and improve production flows by highlighting inefficiencies. To develop a VSM, Rother and Shook (2003) propose the following steps:

Since VSM does not encompass all product families, the first step is to select the specific product family to be analysed. Typically, the one most critical to the company is chosen first.

The current state map is then created using standard symbols and key performance indicators such as cycle time, setup time, lead time, shift availability, workforce allocation per process, number of shifts, batch size and average inventory between processes. This step helps identify bottlenecks, major sources of waste and existing value streams across the supply chain. Based on the analysis of the current state, a future state map is designed. This version integrates improvements focused on eliminating waste and enhancing value creation. The same indicators are applied, but this time with a focus on optimised processes and improved flow. Finally, an action plan is developed to implement the proposed improvements, often using Lean tools and techniques to guide the changes.

Digital Technologies in Construction: BIM, RFID, IoT and Emerging Smart Systems

The digital transformation of the construction sector has profoundly reshaped operational efficiency, safety performance, and supply chain sustainability. Among the most influential technologies are Building Information Modeling (BIM), Radio Frequency Identification (RFID) and the Internet of Things (IoT), which together form the technological backbone of smart construction ecosystems. When combined, these tools improve real-time visibility, reduce uncertainties and enhance coordination across project stakeholders.

Integration of BIM with RFID has demonstrated significant potential for real-time tracking of materials, prefabricated elements and equipment throughout their lifecycle. BIM–RFID coupling can reduce material search time and improve prefabrication assembly accuracy (Brandín & Abrishami, 2024; Costin et al., 2015). This integration enhances transparency across the supply chain and supports just-in-time deliveries in modular and off-site construction.

RFID technologies have also been widely recognized for their contribution to safety and workforce monitoring. According to Li et al. (2018), RFID-enabled safety systems enable continuous monitoring of worker proximity to hazardous zones, significantly reducing accident risk and enabling proactive safety interventions.

IoT sensors further expand the capabilities of construction logistics by enabling predictive maintenance, environmental monitoring and dynamic control of material flows. IoT-based solutions have improved equipment utilisation and reduced unplanned downtime in large-scale construction projects (Wan & Bai, 2020). Embedded sensors support automated data capture on material consumption and site conditions, enabling more accurate forecasting and waste minimization.

Integrated Project Delivery (IPD) models reinforce these technological advancements by promoting collaboration, real-time communication, and shared accountability among stakeholders. Studies show that IPD combined with digital platforms improves decision-making efficiency and reduces cost deviations (Qiao, 2023; Kent & Becerik-Gerber, 2019).

Methodology

This study employs a narrative/conceptual literature review based on a qualitative, exploratory and descriptive conceptual research design to analyse inventory management practices in the Portuguese construction sector and compare them with those of the retail and manufacturing industries. A qualitative methodology was selected to capture the specificities, challenges and practices based on non-quantifiable data (Creswell & Poth, 2018).

Data collection was carried out through an extensive literature and document review involving scientific articles, sectoral reports, books and publications from official organisations. Priority was given to studies focused on inventory management, logistics and digital technologies in the analysed sectors. Most sources were published within the last decade and selected primarily from Scopus and Web of Science, ensuring up-to-date and contextually relevant information.

Additionally, industry reports and sectoral publications from construction, retail and manufacturing organisations were examined to identify concrete practices, challenges and adopted inventory control solutions (Yin, 2015).

Data analysis followed Bardin's (2011) content analysis methodology, categorizing information into four thematic dimensions: (1) inventory management characteristics, (2) sector-specific challenges, (3) technological applications and (4) cross-sector comparisons. This enabled the development of a comparative framework and the identification of the main factors influencing logistics performance in each sector.

The main limitation of the study is the absence of primary data collection, such as interviews or surveys with sector professionals. This limitation results from time constraints and restricted access to field data. Future studies are encouraged to employ empirical approaches to deepen the analysis (Bryman, 2016).

Analytical Framework

Following Jabareen (2009), a conceptual framework was developed to synthesise the relationships identified in the literature and to explain how ERP and BIM integration contributes to material flow visibility and, ultimately, to cost control in construction projects. Previous studies indicate that digital integration and information sharing improve coordination across construction supply chains (Papadonikolaki & Wamelink, 2017), supporting the development of the conceptual framework proposed in this study.

Figure 1. Proposed conceptual framework linking construction-specific challenges, ERP–BIM integration, material flow visibility and cost control outcomes

Construction Challenges	Digital Integration	Information Visibility	Coordination	Operational Performance	Cost Performance
fragmented supply chain	ERP	real-time inventory	collaboration	less waste	cost control
decentralised sites	BIM	material tracking	planning	fewer delays	budget control
inventory uncertainty	RFID/IoT	traceability	procurement	logistics efficiency	profitability

Source: Adapted from the literature on conceptual framework development and BIM-enabled supply chain integration (Jabareen, 2009; Papadonikolaki & Wamelink, 2017).

The framework suggests that the operational characteristics of the construction sector create a need for greater material flow visibility. ERP and BIM integration act as enabling mechanisms that improve information quality, coordination and inventory control, leading to operational improvements and enhanced cost and budget performance.

Specific Challenges in the Construction Sector

Inventory management in the construction sector is inherently complex due to the transient, decentralised and project-based nature of construction operations. In Portugal, these challenges are reinforced by fragmented supply chains, limited integration among project participants and relatively low levels of supply chain management maturity, which hinder the adoption of standardized logistics processes and digital management practices (Arantes et al., 2015).

Although digital technologies have the potential to mitigate supply chain fragmentation, their adoption in construction remains uneven. Unlike manufacturing or retail – where supply chains are integrated, automated and data-driven – the construction sector relies heavily on reactive, loosely coordinated networks. Supplier relationships are typically short-term and project-specific, resulting in reduced visibility of material availability, longer lead times and inconsistent delivery performance (Brandín & Abrishami, 2024). International research confirms that fragmented subcontracting structures significantly increase uncertainties and logistics risks (Chowdhury, 2025).

In Portugal, dependence on small local subcontractors without interoperable information systems further aggravates data fragmentation and operational inefficiencies. Despite European Union initiatives promoting digitalisation, many Portuguese firms still lag behind in adopting BIM, ERP, RFID or IoT-based inventory management tools (Siagian & Jie, 2021). Barriers include high implementation costs, low digital literacy and organisational resistance to process change.

Material losses remain a persistent challenge in construction projects due to inefficient inventory control, inadequate storage conditions, poor handling practices and fragmented coordination among project participants. These inefficiencies reduce project profitability and increase environmental impacts through unnecessary material waste and inefficient resource use (Formoso et al., 2002; Poon et al., 2004). Although environmental regulations have become more stringent, the lack of traceability and standardised inventory management procedures continues to hinder systematic waste reduction and resource optimisation. Overall, the challenges faced by the construction sector arise from the combined effects of operational complexity, fragmented supply chains, technological limitations and organisational inertia, reinforcing the need for integrated digital systems and structured logistics strategies.

As highlighted by Ferreira (2021) in "Development of an Inventory Management Policy at Wurth Portugal", an effective policy can transform resource management into a competitive advantage when supported by robust data and digital processes.

Enterprise Resource Planning (ERP) systems enable data integration across various company departments, allowing real-time stock movement tracking and automated replenishment management (Luz et al., 2020). ERP systems assure real-time cost and inventory visibility, particularly in complex and decentralised environments (Haddara & Elragal, 2015). A modern ERP system should include modules for financial management, logistics, inventory control, order processing, warehouse management and material tracking. Additional modules often include production management, CRM and human resources.

In Portugal, platforms like Primavera Construction and SAP Business One for Engineering have been adopted, mainly by larger firms. However, implementation costs, required process reengineering and training complexity remain major obstacles for micro and small enterprises.

Developing collaborative relationships with suppliers and subcontractors improves delivery coordination, reduces uncertainty and facilitates logistics planning by strengthening information sharing and supply chain integration (Papadonikolaki & Wamelink, 2017). Building Information Modeling (BIM) enables 3D simulation of construction projects, integrating structural, financial and logistical data. This technology is key for accurate material planning and waste prevention (Brandín & Abrishami, 2024). In Portugal, BIM adoption has been encouraged by public procurement requirements. It serves as a collaborative digital platform that consolidates detailed information on geometry, materials, technical properties and construction processes. It operates as a real-time, shared database updated by all project stakeholders, supporting efficient coordination and early conflict detection (Eastman et al., 2011).

BIM offers proven benefits such as enhanced communication among multidisciplinary teams, improved schedule and cost control, higher project quality and increased sustainability and energy efficiency through integrated environmental performance analysis (Azhar, 2011; Brandín & Abrishami, 2024). It also facilitates building maintenance and operations.

Organisational culture is widely acknowledged as a critical element in management theory and practice, becoming a core component of strategic discourse (Flamholtz, 2001).Zago (2000) identified several key components of organisational culture, including values, beliefs, knowledge, cognition, assumptions, meanings and suppositions.

Numerous factors influence the development and manifestation of organisational culture, such as the company's history, product offerings, market dynamics, adopted technologies, strategic orientation, workforce profile, managerial style and even broader national culture (Needle, 2010). Gramsci & Sader (1990) further suggest that, because culture is embedded in everyday language and routine practices, it can constrain individuals' ability to conceive of alternatives to prevailing norms and assumptions.

Beyond organisational culture, national cultural characteristics also influence the implementation and effective use of ERP and BIM technologies in construction projects. According to Hofstede (2001), cultural dimensions such as uncertainty avoidance, power distance and long-term orientation shape organisational attitudes towards innovation, standardisation and technological change. In construction projects, these cultural characteristics may influence the willingness of organisations to adopt integrated digital platforms such as ERP and BIM, particularly where implementation requires collaborative workflows and information sharing across multiple stakeholders. Organisational culture and strategic capabilities are significant predictors of BIM adoption, highlighting the importance of leadership commitment, innovation-oriented values and digital collaboration practices (Zakariyyah et al., 2021). Consequently, successful ERP–BIM implementation depends not only on technological capabilities but also on organisational and cultural conditions that facilitate digital transformation.

Conclusion

This study proposed a conceptual framework explaining how the integration of Enterprise Resource Planning (ERP) systems and Building Information Modeling (BIM) enhances material flow visibility and supports cost control and budget performance in construction projects. By addressing the distinctive characteristics of the construction sector – namely its decentralised operations, project-based structure and fragmented supply chains – the study contributes to a better understanding of the limitations of traditional inventory management approaches in this context.

Inadequate visibility of material flows, limited digital integration and weak coordination among supply chain actors are major contributors to material losses, budget overruns, procurement inefficiencies and project delays. In contrast, the integration of ERP and BIM enables greater transparency, real-time information sharing and improved coordination across project stakeholders. ERP systems provide centralised control over decentralised operations, while BIM supports more accurate planning, forecasting and resource allocation. Together, these technologies strengthen decision-making processes and contribute to improved financial and operational performance.

From a theoretical perspective, this research contributes by synthesizing fragmented literature on construction logistics, inventory management and digital technologies into a unified conceptual framework linking ERP–BIM integration, material flow visibility and cost control outcomes. From a managerial perspective, the findings highlight the importance of investing in integrated digital solutions and fostering data-driven coordination practices to improve inventory control and budget governance across construction projects.

Addressing the Research Question 1, the literature shows that construction differs from manufacturing and retail because of decentralised job sites, fragmented supply chains, project-based production and high demand uncertainty, making inventory management considerably more complex. Related to Research Question 2, the review indicates that ERP–BIM integration improves inventory visibility, real-time information sharing, procurement planning and coordination among stakeholders, contributing to better material flow control and cost performance. Concerning Research Question 3, the analysis suggests that managers should invest in integrated digital platforms, organisational training, supplier collaboration and standardised information management practices to maximize the benefits of digital transformation.

These findings also suggest that successful digital transformation in construction depends not only on technological integration but also on organisational and cultural readiness to support collaborative practices and information sharing.

Research limitations

Related to its conceptual nature and reliance on secondary data sources. As no primary empirical evidence was collected, the proposed framework should be considered exploratory.

Future research

For further outcomes it would be interesting to analyse the relationships identified in this study through surveys, interviews, longitudinal analyses and multiple case-study designs.

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