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BLOCKCHAIN TECHNOLOGY ADOPTION IN CONSTRUCTION MANAGEMENT: A SYSTEMATIC LITERATURE REVIEW BASED ON THE TOE FRAMEWORK ANALYSIS

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Abstract

The construction sector is a major contributor to the global economy but continues to face persistent challenges, including inefficiencies, low transparency, and frequent disputes. Blockchain technology offers potential solutions through its decentralized, transparent, and secure data management features. This study aims to analyze the benefits, adoption drivers, and barriers of blockchain implementation in construction management using the Technology–Organization–Environment (TOE) framework. A Systematic Literature Review (SLR) method was employed, examining peer-reviewed articles published between 2010 and 2025. The findings indicate that blockchain provides key benefits, including enhanced transparency, improved payment efficiency, supply chain integration, dispute reduction, and better document management and project monitoring. The main drivers of adoption include technological factors (relative advantage and compatibility), organizational factors (top management support and organizational readiness), and environmental factors (regulatory support and competitive pressure). However, several barriers remain, such as limited industry readiness, lack of technical expertise, system integration complexity, and regulatory uncertainty. This study contributes to a structured understanding of blockchain adoption in construction and provides practical insights for developing more effective implementation strategies.

Keywords: Blockchain, Construction Management, TOE Framework, Systematic Literature Review

Introduction

Construction is a strategic sector that significantly contributes to the global economy, accounting for approximately 6–10% of global GDP and playing a vital role in job creation and infrastructure development (Rwelamila & Ogunlana, 2015). Despite its importance for economic growth, the construction industry continues to face fundamental challenges, including inefficiencies, declining stakeholder trust due to disputes, and suboptimal financial performance (Ameyaw et al., 2016). The involvement of multiple parties in construction projects creates risks of disputes, data discrepancies, and potential fraud in administrative and financial processes due to information asymmetry (Murray & Dainty, 2013).

However, these challenges are not only general in nature but are also reflected in specific issues encountered in practice, such as project termination due to delayed payments to contractors and vendors (Habetemeherit et al., 2025), low levels of project transparency that negatively affect project performance and outcomes (Zhang, 2021), unclear or incomplete contract documentation (Hanák & Vítková, 2022), and the continued reliance on conventional methods that lead to inefficiencies in project management (Olusola & Phung, 2025).

Addressing these issues requires improvements in workforce capabilities, technology adoption, and transparency, which are increasingly recognized as critical factors. A report by McKinsey & Company highlights that construction stakeholders widely acknowledge the importance of digital technologies for industry sustainability. Technologies such as the Internet of Things (IoT), Big Data, Blockchain, and others have significant potential to provide efficient solutions and process optimization (J. Li et al., 2019). Given that the construction sector has one of the lowest levels of digitalization compared to other industries, the adoption of new technologies has been identified as a key transformation necessary to enhance and replace traditional approaches (Pattini et al., 2020).

In recent years, blockchain technology has attracted considerable attention (C. Li et al., 2022). It offers promising solutions to address various issues due to its inherent characteristics, such as immutability, transparency, and decentralization (Qian & Papadonikolaki, 2020). This technology is designed to store not only financial transactions but virtually any type of valuable data. Blockchain is a fundamental innovation that offers several key advantages: (1) Security, as data stored on the blockchain is extremely difficult to alter or hack—any modification to a single block invalidates all subsequent blocks; (2) Transparency, as all transactions are visible to participants, enhancing accountability and trust; and (3) Efficiency, as it reduces the need for intermediaries, enabling faster and more efficient transactions. Blockchain is part of the broader category of Distributed Ledger Technologies (DLTs) and is defined as a "trustless" system because it enables decentralized information storage that ensures trust, immutability, and data integrity without relying on a central authority (Lai & Lee Kuo Chuen, 2018).

Although blockchain has significant theoretical value, its effective implementation in construction management requires a comprehensive understanding of its benefits, the factors driving its adoption, and the challenges encountered during implementation. The Technology–Organization–Environment (TOE) framework provides a holistic perspective for evaluating technology adoption by examining technological attributes, organizational readiness, and external environmental dynamics that collectively influence adoption success. However, existing systematic literature reviews still exhibit several limitations, including the limited use of the TOE framework as a basis for analyzing blockchain adoption in construction. Moreover, most studies focus on developed countries, thus underrepresenting the context of developing countries such as Indonesia. In addition, systematic mapping of adoption drivers and barriers remains limited and has not yet been fully integrated into a comprehensive analytical framework.

Based on these gaps, this study aims to address the lack of structured knowledge regarding blockchain adoption in construction management through a systematic and comprehensive literature review using the TOE framework. Specifically, this study is guided by the following research questions: (RQ1) What are the main benefits of blockchain implementation in construction management?; (RQ2) What factors drive blockchain adoption based on the technological, organizational, and environmental dimensions of the TOE framework?; and (RQ3) What are the key challenges and barriers in implementing blockchain in the construction sector?.

Research Methods

This study employs the Systematic Literature Review (SLR) method, which enables a comprehensive identification of patterns, trends, and research gaps in the topic of blockchain technology adoption in construction management. This approach is selected as it ensures a systematic, transparent, and replicable literature review process with rigorous methodological standards. The primary objective of this SLR is to identify, evaluate, and synthesize relevant studies related to the implementation of blockchain in the construction industry, particularly from a technology adoption perspective based on the Technology–Organization–Environment (TOE) framework. In addition, this study aims to uncover the key factors influencing adoption, as well as to identify research trends and future directions for blockchain development in the context of construction management.

The SLR method is conducted through structured stages, including literature identification, screening, eligibility assessment, and synthesis of relevant study findings. This process follows the principles of transparency and replicability to ensure that the review results achieve high validity and reliability (Sudjani & Putra, 2025).

Planning Stage

At the planning stage, the research questions guiding this systematic literature review were formulated based on the issues identified in construction management and the potential of blockchain technology as a solution. The data used in this study consists of secondary data obtained through comprehensive literature searches, without conducting direct field research or empirical data collection. Nevertheless, the data were derived from rigorous literature reviews and reputable academic sources. The research questions (RQs) guiding this systematic literature review are as follows:

RQ1. What are the benefits of blockchain technology in construction management?

RQ2. What factors influence the adoption of blockchain in construction management based on the Technology–Organization–Environment (TOE) framework?

RQ3. What are the main barriers and challenges in implementing blockchain in construction management?

Implementation Stage

In the implementation stage, the literature search process required a considerable amount of time to identify and collect relevant articles suitable for a systematic literature review. Since this study relies entirely on secondary data, it is essential to identify high-quality journals that align with the research objectives to ensure the credibility and reliability of the references. A systematic search strategy was employed across multiple academic databases, including Scopus, Web of Science, IEEE Xplore, ScienceDirect, and Google Scholar. The search utilized Boolean operators to refine keywords related to blockchain technology, construction management, and adoption factors. Specific search strings included: ("blockchain" OR "distributed ledger") AND ("construction" OR "construction management" OR "project management" OR "construction industry") AND ("technology adoption" OR adoption model" OR "TOE framework" OR "technology-organization-enviroment"). The literature search was confined to peer-reviewed articles published between 2010 and 2025 to maintain their technological relevance and incorporate the latest discoveries. Moreover, extra sources were uncovered through backward citation, which entails scrutinizing the reference lists of the chosen studies, and forward citation, which involves analyzing subsequent research that references those selected articles.

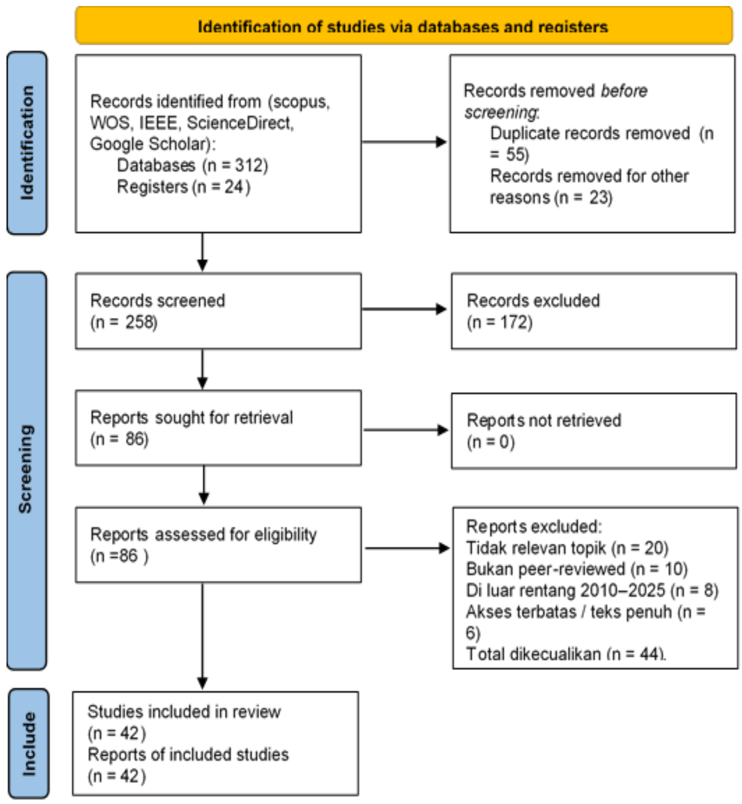

Figure 1. PRISMA Flow Diagram of Literature Selection Process

Quality Assessment Criteria

The SLR methodology supports a structured quality assessment process to ensure that selected studies sufficiently address the predefined research questions. The quality assessment was guided by the following questions:

QA1: Was the article published in a reputable journal or conference proceeding between 2010 and 2025?

QA2: Does the article provide information related to the application of blockchain in construction (RQ1)?

QA3: Does the article provide information relevant to the influencing factors of adoption (RQ2)?

QA4: Does the article provide insights into the challenges and barriers to implementation (RQ3)?

Inclusion and Exclusion Criteria

The procedure for selecting articles was directed by clearly defined inclusion and exclusion criteria to uphold consistency and guarantee the relevance of the literature under review. The inclusion criteria included: articles from peer-reviewed journals or conference proceedings, publications released between 2010 and 2025, materials written in English or Bahasa Indonesia, and studies that are directly pertinent to the research subject. In contrast, the exclusion criteria consisted of: non-academic sources such as blogs, news pieces, and opinion editorials; articles that were not readily accessible; and publications that failed to align with the primary focus of the investigation.

Reporting

The final stage of the Systematic Literature Review (SLR) process involves the processing and analysis of the selected research sources for systematic examination. After the screening of journals using the SLR methodology, conclusions are drawn based on the findings by referring to sources that are relevant to the research topic and that provide the necessary information. Each selected study is analyzed and mapped to indicate its contributions to the predefined Research Questions (RQs), ensuring that all findings are systematically categorized and aligned with the study's objectives.

Research Results and Discussion

Problems in Construction Management

In construction projects, particularly those still relying on traditional management approaches, numerous significant challenges hinder smooth project execution. These challenges are not merely operational issues; rather, they reflect deeper structural problems rooted in information asymmetry, the complexity of multi-stakeholder governance, and misaligned incentives among project owners, contractors, consultants, subcontractors, and suppliers. Understanding these root causes is essential to evaluate how blockchain technology can function as a systemic solution rather than merely a temporary fix. The first major challenge is payment delays. Delayed payments significantly affect contractor performance by disrupting workflows and cash flow (Riswanto et al., 2023), yang pada akhirnya memengaruhi jadwal proyek which ultimately impacts project schedules (Habetemeherit et al., 2025). Nearly 98% of construction projects experience cost overruns or schedule delays, with approximately 9 out of 10 projects exceeding their initial budgets (Mahmudnia et al., 2022; Shojaei, 2019). The root cause of this issue lies in the reliance on manual verification processes and intermediaries that slow down payment approvals, highlighting the need for blockchain's capability to automate milestone-based payments through smart contracts.

The second major challenge is the lack of transparency. The absence of real-time, verifiable project monitoring makes it difficult for stakeholders to track financial transactions and construction progress, creating conditions prone to disputes (Perera et al., 2020; Zhang, 2021). Information asymmetry where different parties possess different information regarding project status is a fundamental governance issue that cannot be adequately addressed by traditional centralized data systems but can be directly resolved through blockchain's distributed ledger architecture.

The third major challenge is the reliance on conventional, paper-based contract management systems. Under traditional models, documentation is often unclear or incomplete, increasing the risk of miscommunication and contractual errors (Hanák & Vítková, 2022; Olusola & Phung, 2025). The centralized storage of contracts and project data also creates a single point of failure and increases vulnerability to data manipulation (Hamledari & Fischer, 2021).

These recurring structural issues payment delays, lack of transparency, and weaknesses in contract management collectively underscore the urgent need for blockchain technology. Blockchain offers immutability to ensure document integrity, transparency for real-time monitoring, and smart contract automation to facilitate payments and enforce compliance.

Blockchain Technology

In 2008, Satoshi Nakamoto introduced the concept of a "block chain" data structure along with a consensus mechanism that enables a group of entities to maintain a distributed ledger of currency transactions (Gasser & Hubaux, 2023). The term blockchain refers to an advanced database system that facilitates transparent and trustworthy data exchanges across a business network. The system stores data in linked blocks arranged in a chronological chain (Plevris et al., 2022). Blockchain functions as a decentralized and distributed digital ledger designed to log transactions across a network of interconnected computers; altering any single block demands modifications to all subsequent blocks, safeguarding data integrity and enabling full traceability.

This technology ensures transaction security by sequentially connecting blocks of data, each containing essential information regarding asset movement (Celik et al., 2024). The blockchain process involves five main steps: (1) authorized users initiate a transaction to be verified by the system; (2) the transaction generates a block representing specific data or actions; (3) this block is distributed to all participating nodes in the network; (4) authorized nodes validate the transaction and append the block to the existing blockchain; and (5) the updated chain is synchronized across the entire network (Turk & Klinc, 2017).

Blockchain possesses three distinct characteristics of particular relevance to construction management. First, immutability: once information is entered into the blockchain, it cannot be changed or erased without generating a permanent record of the modification, which substantially bolsters accountability and regulatory compliance, directly addressing the problem of document falsification and contract disputes (Celik et al., 2024; Saygili et al., 2022). Second, transparency: all authorized participants have access to shared transaction records in real time, resolving information asymmetry between project owners, contractors, and subcontractors (Perera et al., 2020; Qian & Papadonikolaki, 2020). Third, smart contract automation: self-executing algorithms embedded in blockchain can automatically trigger milestone-based payments when predefined conditions are met, eliminating reliance on manual intermediaries and directly addressing the payment delay problem (Eze & Ameyaw, 2025). These three features map precisely onto the three core construction challenges identified above, making blockchain a structurally appropriate solution for the industry's most persistent inefficiencies.

Findings (RQ1): Benefits of Blockchain in Construction Management

A thematic synthesis of the 42 included studies reveals five principal benefit domains through which blockchain technology addresses core construction management challenges.

The first benefit domain is enhanced transparency and accountability. Blockchain provides a distributed, tamper-proof ledger where every transaction and data modification is traceable in real time by all authorized parties connected to the network (Perera et al., 2020; Qian & Papadonikolaki, 2020). This level of transparency is crucial in the construction industry, which typically involves multiple stakeholders with diverse and sometimes conflicting interests project owners, main contractors, subcontractors, suppliers, and consultants all of whom benefit from access to a single, immutable source of truth regarding project status, payment history, and contractual compliance.

The second benefit domain is payment and financial management optimization. Blockchain-based payment systems show considerable potential in addressing cash flow issues that are endemic to construction supply chains. Eze and Ameyaw (Eze & Ameyaw, 2025) reported an average reduction of 65% in payment processing time and a 45% decrease in disputes through smart contract implementation. Milestone-based automated payments eliminate delays caused by manual verification processes while providing a transparent audit trail for all financial transactions. Furthermore, blockchain eliminates the need for third-party intermediaries in transaction verification (Strebinger & Treiblmaier, 2024), thereby reducing operational costs and accelerating payment cycles.

The third benefit domain is supply chain integration and material traceability. Blockchain enables end-to-end tracking of construction materials from manufacturing to installation. A study by (Thompson & Rust, 2023) reported an 80% increase in material verification efficiency and a 90% reduction in counterfeit materials through blockchain implementation. This level of traceability supports sustainability initiatives by enabling verification of environmental certifications, ethical sourcing practices, and quality standards throughout the construction supply chain.

The fourth benefit domain is dispute reduction and document management. Immutable document storage and version control capabilities help resolve chronic issues related to document authenticity and regulatory compliance. A study by (Chen et al., 2022) reported a 70% reduction in document-related disputes and a 50% increase in audit efficiency through blockchain-based document management systems. In their exploratory literature review (Scott et al., 2021) concluded that blockchain's tamper-proof audit trails transform dispute resolution from a confrontational process into collaborative problem-solving, enabling involved parties to quickly access shared records to trace root causes and reach mutually beneficial agreements.

The fifth benefit domain is progress monitoring and quality assurance. Integration with IoT sensors and Building Information Modeling (BIM) systems enables real-time, immutable recording of construction progress and quality metrics. This combination allows for objective progress verification, reduces disputes over milestone achievement, and supports accurate milestone-based payment triggering (J. Li et al., 2019). In contract management specifically, studies show a 55% reduction in contract disputes and 40% faster dispute resolution through blockchain-enabled smart contracts (Shrimali & Patel, 2022).

Findings (RQ2): TOE Drivers of Blockchain Adoption in Construction Management

Findings from the literature highlight that technological factors play a crucial role in driving blockchain adoption within the construction industry. One of the primary aspects is relative advantage, which refers to the degree of efficiency and economic benefits perceived by an organization from implementing a new technology. This advantage not only enhances competitiveness but also contributes to strengthening organizational reputation. According to the diffusion of innovation theory, the likelihood and speed of technology adoption are strongly associated with how clearly these benefits are perceived. A study by (Wong et al., 2020) emphasizes that relative advantage significantly influences organizational intentions to adopt blockchain, particularly in the context of supply chain operations among small and medium enterprises in Malaysia. Similarly, (Kapoor et al., 2014) found that perceived usefulness of a technology is strongly impacted by its relative advantage, making it a key indicator of organizational readiness and motivation for innovation adoption. In addition to relative advantage, compatibility is another essential factor that determines the success of blockchain adoption. Compatibility refers to how well the new technology aligns with existing systems, business processes, and organizational culture. The higher the compatibility, the more likely it is for adoption to occur smoothly. (Oliveira et al., 2014) and (Thiesse et al., 2011) assert that compatibility with managerial requirements and business practices is a critical determinant of innovation adoption. In the construction context, (Fernando et al., 2021) confirm that perceived alignment of blockchain with operational needs serves as a key motivator for organizations to adopt the technology. Thus, construction firms are more likely to adopt blockchain when they perceive it as compatible with their existing organizational practices and values. The third important factor is cost. The adoption of blockchain technology involves relatively high initial investments, including the procurement of technology, training of personnel, and development of customized solutions suited to the construction sector. (Toufaily et al., 2021) argue that high implementation costs can be a significant barrier to adoption, as seen in studies related to mobile commerce and e-learning platforms. Furthermore, (Zainab et al., 2017) note that blockchain, being a relatively new and complex technology, requires skilled professionals and significant financial commitment. This poses a substantial challenge for small and medium-sized construction firms that often face financial constraints. Additionally, because the benefits of blockchain may not be immediately visible in the short term, financial risks become a major consideration in the decision-making process.

On the other hand, organizational factors also play a crucial role in determining the success of blockchain adoption. One of the most critical elements is top management support, which is considered the most vital organizational factor in facilitating blockchain implementation. Strategic commitment from top management not only enables the adequate allocation of financial and human resources, but also fosters internal legitimacy that encourages active participation across all organizational units. It reduces resistance to change by clearly communicating the vision of digital transformation and ensures that blockchain initiatives are integrated into the company's long-term business strategy, gaining priority within the organizational agenda amidst competition from other technological innovation projects. In the initial stages of blockchain adoption, support from top management is essential to overcome internal resistance and to motivate organizational members by providing clear direction and ensuring the availability of necessary resources and funding. Numerous studies in the construction industry emphasize that this support is critical for integrating new technologies (Beliz & Kutluhan, 2017) into existing business processes, thereby facilitating learning and the dissemination of the innovation (Ramdani et al., 2013). In addition, organizational readiness to adopt blockchain is a multidimensional construct that reflects an organization's technical capabilities, human resources, IT infrastructure, and financial capacity to integrate blockchain systems into its existing business operations. Organizational readiness encompasses both the capability and the willingness of a company to adopt new innovations, including management's readiness to invest and the cognitive, human, and technological resources available. Research by (Mi & Wei, 2020) confirms that organizational readiness has a positive influence on the level of innovation adoption within the construction sector. Awareness of the need for change, availability of financial resources, workforce expertise, and technical competence serve as the foundational pillars for successful blockchain adoption and implementation in construction firms.

In terms of environmental factors, the first is regulatory support, which plays a vital role in encouraging the adoption of blockchain. According to research by (Orji et al., 2020) government policy support is one of the three main factors influencing blockchain adoption in the freight logistics industry. Similarly, (Suwanposri et al., 2021) emphasize that government policy and regulatory frameworks are critical environmental components that influence the adoption of blockchain technology. In Indonesia, blockchain regulations have begun to gain formal recognition through Peraturan Pemerintah Nomor 28 Tahun 2025, which classifies blockchain as a national strategic technology and acknowledges it as part of the country's digital infrastructure. This regulation also streamlines the licensing process for blockchain-based businesses through the issuance of a Business Identification Number (NIB) and Standard Certificates, allowing developers and industry actors to operate more transparently and legally. Furthermore, the regulation stipulates that blockchain projects must remain active and productive for at least three years to receive official recognition from the government. It also outlines monitoring procedures and administrative sanctions for violations. Through this regulation, the Indonesian government demonstrates its commitment to developing a secure, trustworthy, and innovative blockchain ecosystem, while affirming blockchain's position as an integral part of the national digital transformation agenda. The second environmental factor is competitive pressure, which refers to the level of pressure a company faces due to intense competition from peers in the same industry (Singh & Mansotra, 2018). In the highly competitive and challenging construction industry, this pressure drives organizations to adopt innovations to improve quality, reduce costs, and enhance operational effectiveness and efficiency. As an emerging technology, blockchain presents opportunities for early adopters to gain a competitive advantage in today's rapidly evolving market. Therefore, competitive pressure is believed to stimulate demand among construction firms for blockchain technology and encourage a more aggressive adoption approach.

Findings (RQ3): Barriers to Blockchain Implementation in Construction Management

Although blockchain technology offers substantial advantages and transformative potential for the construction industry, its implementation remains challenged by a range of complex and deeply rooted issues. As highlighted by (Celik et al., 2024), key barriers to adoption include resistance to change, a lack of adequate technical expertise, and ambiguity in the legal and regulatory frameworks governing its use. The multifaceted nature of these challenges calls for a deeper understanding and a strategic, holistic approach to effectively address and overcome them.

The readiness of the construction sector to adopt blockchain remains a significant obstacle. As noted by (Hexu et al., 2023), major hurdles include the absence of standardized readiness assessment methodologies, insufficient industry-wide evaluations, and the lack of quantitative frameworks to measure the cost-benefit dynamics of blockchain implementation. Additionally, (Haitao et al., 2022) emphasize that industry preparedness is a critical determinant often hindering successful adoption. This highlights a substantial gap between the innovative potential of blockchain technology and the industry's current capacity to effectively implement it. Furthermore, (Gurgun et al., 2022) identify a range of other challenges, including limited technical knowledge of cryptocurrency, unstable market valuations, narrow market opportunities, security vulnerabilities, mandatory disclosure of personal data, uncertainties surrounding long-term use, and restrictive government regulations on cryptocurrency applications. These limitations are not confined to technical dimensions alone, but also extend to strategic and operational implications, underscoring the need for a broader understanding of blockchain's integration into industry practice.

The integration of blockchain with existing systems and processes in the construction industry also poses both technical and organizational difficulties. As explained by (Waqar et al., 2024), a key obstacle lies in the difficulty of aligning blockchain technology with the current infrastructure. Many construction firms have already made significant investments in established systems such as project management tools, accounting software, and Building Information Modeling (BIM) platforms. Therefore, integration requires not only technical compatibility but also fundamental changes to existing business processes and operational workflows.

Conclusion

This systematic literature review examines the adoption of blockchain technology in construction management using the TOE framework as the analytical structure. The key findings, contributions, implications, limitations, and future research directions are summarized as follows: (1) Blockchain offers five principal benefit domains in construction management payment optimization (65% reduction in processing time), dispute reduction (45–70% decrease), material traceability (80% improvement in verification efficiency), document management, and progress monitoring; (2) The TOE framework reveals three categories of adoption drivers: technological factors (relative advantage, compatibility, cost), organizational factors (top management support, organizational readiness), and environmental factors (regulatory support, competitive pressure); and (3) Key barriers include industry readiness deficits, system integration complexity, ROI uncertainty, and the general, non-sector-specific nature of existing regulatory frameworks including Government Regulation No. 28 of 2025.

This review makes three contributions to the literature. First, it provides the first structured application of the TOE framework to map blockchain adoption drivers and barriers specifically in construction management. Second, it addresses the gap in prior reviews by incorporating the developing-country context, particularly Indonesia. Third, it synthesizes quantitative benefit metrics from multiple studies, providing a more precise picture of blockchain's impact potential.

For successful implementation, the following strategic actions are recommended: (1) adopt a phased rollout beginning with high-value, high-impact use cases such as milestone-based smart contract payments; (2) demonstrate long-term organizational commitment through top management endorsement and dedicated resource allocation; (3) invest in human capital development through blockchain training programs; (4) advocate for the development of sector-specific regulations addressing smart contract enforceability, data privacy, and dispute resolution in construction; and (5) foster cross-industry collaboration to develop interoperability standards. Widespread blockchain adoption is projected to commence within government agencies and stateowned enterprises within the next 5 to 10 years, serving as an anchor for broader industry diffusion.

This review is subject to several limitations. The literature is predominantly drawn from English-language sources, potentially underrepresenting research from non-English-speaking construction markets. The quantitative benefit figures cited (e.g., 65% reduction in payment times) are derived from specific implementation contexts and may not generalize across all construction environments. Additionally, the rapidly evolving regulatory landscape particularly in Indonesia means that findings regarding regulatory support may require updating as new policies emerge.

Future studies should (1) develop and validate quantitative readiness assessment frameworks for blockchain adoption in construction; (2) conduct empirical research on blockchain implementation outcomes in Indonesian construction projects; (3) investigate the specific legal and contractual adaptations needed to make smart contracts enforceable under Indonesian civil law; and (4) explore the integration of blockchain with BIM and IoT in construction management contexts across developing countries.

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