TOWARD SMART CONTRACT ADOPTION IN VIETNAM'S CONSTRUCTION SECTOR: CHALLENGES AND A CONCEPTUAL IMPLEMENTATION FRAMEWORK

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(Received: February 23, 2026; Revised: May 15, 2026; Accepted: June 05, 2026)
DOI: 10.31130/ud-jst.2026.24(7B).595E

Abstract – The construction sector is increasingly exploring smart contracts (SCs) to resolve persistent operational challenges, such as payment delays and disputes. This study systematically analyzes SC and Distributed Ledger Technology (DLT) deployments globally and in Vietnam, identifying key legal, technical, and organizational constraints hindering domestic adoption. To bridge these gaps, a five-step implementation framework tailored to Vietnam's institutional and market conditions is proposed. The framework emphasizes incremental adaptation using regulatory sandboxes, a hybrid architecture integrated with Building Information Modeling (BIM), and fiat-based payment mechanisms. The findings highlight that successful adoption depends primarily on institutional readiness and regulatory alignment rather than the technology itself, advocating a phased approach aligned with local industry capabilities.

Key words - Smart contract; construction digitalization; blockchain; distributed ledger technology; implementation framework

1. Introduction

The construction sector's productivity is historically hindered by technological underdevelopment and was the second lowest in global digitalization during the industry 3.0 [1]. This setback is characterized by fragmentation, argumentative relationships and chronic payment delays [2, 3]. Moreover, the chained payment failures and disputes are primary causes of small and medium-sized enterprise (SME) insolvency in this domain [4].

Meanwhile, the smart contract (SC) emerges as a potential solution to these persistent barriers. SCs operate as digital agreements that leverage the immutable record of a blockchain mechanism to provide automated execution of tasks, primarily for automated progress payments where funds are released once predefined requirements are verified [5]. Blockchain functions as a public cryptographic ledger and decentralized network that provides the secure, tamper-proof infrastructure required for hosting these contracts. In a broader context, Distributed Ledger Technology (DLT) encompasses these decentralized databases and is utilized to secure escrowed capital and ensure the reliability of transactions before any data or funds are released [6, 7]. However, the expectation of new technology is often outpaced by reality and has a low return on investment if the target business necessities are not thoroughly defined [8]. For example, SC rely heavily on off-chain data, which consists of information and datasets stored outside the blockchain network. These external inputs act as oracles to trigger contract logic, but this dependency introduces severe execution risks if the external data is inaccurate or fragmented. To resolve data constraints, Building Information Modeling (BIM) integration connects extensive project datasets with blockchain systems to enable automated design compliance and verification. Because blockchain cannot efficiently process large BIM files, a hybrid architecture is typically required where the design data is stored in centralized systems while the DLT handles the on-chain verification and execution.

Some corporate enthusiasm is driven more by public hype and exaggerated expectations aimed at speculative gains than by genuine technological breakthroughs [1, 9]. Furthermore, global public cryptographic ledger projects often stall at the pilot phase due to the disconnect between technology, comprehensive policy, and governance design [10]. To respond to the global shift to SCs, the Vietnamese government mandates national digital transformation which includes virtual signatures and electronic contracts [11, 12]. In addition, the Ministry of Construction (MOC) explicitly targets Digitalization and BIM as a leading agenda [13]. Nonetheless, practical adoption in developing economies is likely stalled by high deployment cost, lack of expertise and cultural resistance [14, 15]. Small-scale projects in ASEAN environment also struggle with centralized legacy systems and a trust deficit [16]. Furthermore, a high degree of skepticism is still persistent regarding the return on blockchain for simpler tasks [8]. Therefore, an adoption strategy specified for the Vietnamese construction sector is still absent.

To bridge these gaps, this study proposes a conceptual framework for SC standardization in construction sector. This approach is synthesized from international lessons, targeting the specific legal, technical and organization contexts of domestic construction industry.

2. Methodology

2.1. Research scope and selection criteria

This study represents a systematic analysis of SC and DLT implementation in the construction sector. The methodology follows a structured method to ensure the literature remains relevant to both the global technological landscape and the specific conditions of Vietnam. The selection process was conducted using major academic databases including Scopus and Web of Science, utilizing search terms combining “smart contract”, “blockchain”, “construction industry”, and “developing economies”.

The literature selection was determined by specific criteria. The timeframe was restricted from 2017 to 2025. The year 2017 was chosen as the baseline because it marks the emergence of foundational academic research on the topic [5] and the start of Vietnam’s formal focus on digital assets under Decision 1255 [17].

To establish an objective benchmark against Vietnam, the study selected global cases based on four distinct environments. These include advanced legal and technical frameworks in the EU and US, known for mature legal structures and BIM integration [18, 19]. The selection also includes state-led initiatives focusing on mega projects in the Middle East and North Africa [4, 20-21], centralized governance models used in China [7, 22-23], and developing peers such as Malaysia and Sri Lanka that share socio-economic hurdles and outdated legacy systems similar to Vietnam [14-16].

For the domestic analysis, the Vietnamese contextual criteria focused on sources addressing core national strategies and practical constraints. This includes the evaluation of government policies, digital transformation programs, stakeholder behavior, digitalization barriers, and the validity of smart contracts under current Vietnamese civil law [24-28]. To ensure a balanced and objective evaluation, bias avoidance and risk assessment criteria were applied. The selection specifically included research that questions the restrictions of blockchain-based solutions and highlights potential risks to avoid “smart technology” hype [8, 9].

2.2. Data extraction and analytical metrics

To provide a structured and objective framework for comparing global and domestic literature, a standardized analytical metric was developed. This metric ensures that the final conceptual implementation framework is not merely theoretical but directly responsive to the legal, technical, and organizational barriers identified during data extraction. Table 1 summarizes the metrics and their applied roles within the study.

The metrics were applied to the reviewed cases through several diagnostic functions. The Application Type category identified the functional roles of SC in construction, ranging from automated progress payments to more advanced applications such as automated design compliance. Stakeholder mapping examined how different actors interact with the technology and helped identify behavioral resistance and the influence of social factors on adoption intention in Vietnam. Implementation phase was used to compare adoption maturity across developed, state-led, and developing contexts. Benefits and Limitations evaluated both performance improvements and operational risks, particularly input errors associated with dependence on off-chain data. Legal Alignment assessed whether automated code could be enforced within different institutional systems by comparing established legal frameworks with Vietnam’s requirement for centralized verification. Technology Architecture identified system design requirements and highlighted the need for hybrid architecture, as blockchain platforms are not well suited for processing large datasets efficiently. Finally, Contextual Feasibility evaluated the applicability of global findings to Vietnam’s SME-dominated construction sector while considering resource constraints and limited digital readiness.

Table 1. *Analytical metrics for data extraction*

Metric	Description	Purpose
Application Type	SC use cases: payment, tracking, compliance [19, 22]	Identify functional roles in construction workflows
Stakeholder Mapping	Stakeholder roles, interactions, resistance, behavioral patterns [28, 29]	Capture barriers and coordination challenges
Implementation State	Application maturity from developed [19] and developing contexts [15, 26]	Benchmark adoption levels in different environments
Benefits & Limitations	Performance gains, risks, constraints, and operational trade-offs [8, 30]	Provide balanced evaluation of smart contract applicability
Legal Alignment	Comparison with regulatory frameworks and contract enforceability [24, 27]	Assess legal feasibility within different institutional systems
Technology Architecture	Integration with BIM, IoT, and off-chain systems [5, 6]	Define system design requirements and compatibility needs
Contextual Feasibility	Adaptation potential within Vietnam institutional and market conditions [24, 28-29]	Filter based on local restrictions and readiness

2.3. Analytical workflow

The primary objective of this research is to develop a conceptual implementation framework to support the systematic adoption of SC in the Vietnamese construction sector. The study addresses the gap between the theoretical potential of the technology and its practical application by examining legal, technical, and organizational barriers specific to the Vietnamese context.

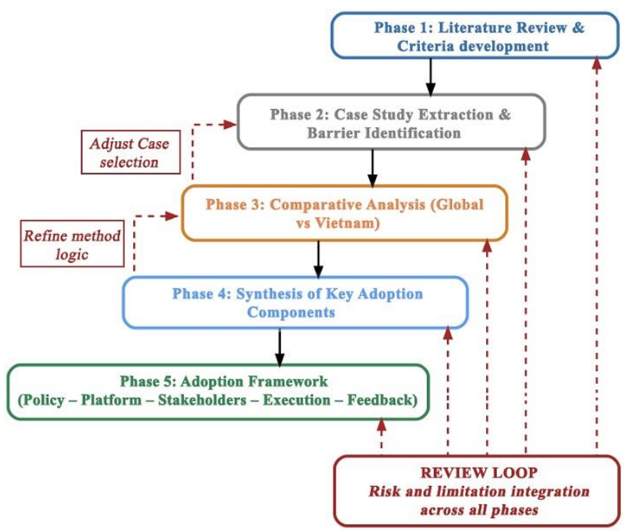

Figure 1. *Analytical workflow of the study*

These objectives form the basis of a five-step analytical workflow that translates global benchmarking data and local constraints into a structured implementation strategy. The multistage socio-technical approach is consistent with established methodological frameworks for digital adoption in construction management [10, 31]. The process includes contextual benchmarking, constraint identification through analysis of the mismatch between immutable code and conventional construction practices, and strategic synthesis. The workflow also incorporates a continuous review and feedback mechanism to support adaptation to the evolving nature of construction processes and reduce the risk of repeating systemic vulnerabilities.

3. Literature and case review

3.1. Global smart contract applications

Recent research shows SC application in global construction industry has shifted from theoretical concepts to practical initiatives throughout multiple project phases [2]. Automated progress payment represents the most practical of these systems in construction at the project level. Particularly, disbursements are executed automatically once requirements are verified or approved designs are achieved [6]. A more advanced approach translates this logic into payment freezing and disbursement mechanisms [22]. The DLT systems are employed where escrowed capital is secured in advance and released upon authentication, thus improving the reliability of the entire procedure.

In addition, these digital tools have been experimented with regulatory and management sandboxes. For instance, BIM-integrated blockchain can support automated design compliance by validating architectural designs against building code requirements, thereby accelerating development approval [19]. On a national scale, DLT have been incorporated directly into Chinese financial infrastructure to enable transactions across multiple financial networks. The Xiong'an New Area case demonstrates how digital ledgers can transfer funds directly to stakeholders of public developments, which improves transparency and reduces delays in project delivery [7].

However, because their performance depends on local conditions and digital capacity, these models are not universally applicable. Specifically, unoptimized adaptations may create additional administrative burdens in straightforward projects without yielding substantial benefits [8]. Likewise, blockchain systems should function as an integrated component within a broader ecosystem designed to solve the construction sector's existing constraints [23]. Furthermore, the mismatch between business capability and market enthusiasm often leads to "smart technology" hype, where these digital tools are promoted for public relations without practical use [1, 9].

3.2. International implementation insights

Analytical comparison confirms that SC integration in construction evolves in different institutional and technological environments (Table 2). Developed markets such as the EU and the United States rely on mature legal structures and BIM integration to enable controlled automation. On the contrary, China demonstrates how state projects can utilize DLT via integrating to central banking systems and public services. However, in emerging digital markets like MENA and Southeast Asia, adoption progress remains uneven and is confined by major limitations such as business strength, digital infrastructure and SME readiness. Ultimately, these findings highlight that the applicability of this digital solution largely depends on regional contexts.

Table 2. *Cross-Context comparison*

Context	Strength	Weakness	SC Role
EU/US [18-19, 32]	Mature legal + BIM	Regulatory complexity	Controlled automation
China [7, 22, 33]	Strong national coordination	Centralization	Financial & system integration
MENA [4, 20-21]	Policy-driven	Asymmetric utilization	Early-stage
Malaysia/Sri Lanka [14, 16]	Similar to Vietnam	Cost, resistance	Limited use

3.3. Structural limitations of SC

Digital ledgers require substantial levels of data accuracy and robust system architecture to ensure viable operation [1, 5]. Nevertheless, these requirements often conflict with dynamic construction environments that frequently undergo schedule changes and designs revisions. [8-9]. Thus, primary barriers to SC implementation are initiated from a misalignment between technology features and traditional construction practices (Table 3). Nonetheless, understanding these limitations is crucial, as they further amplify in the developing digital environment of Vietnam.

Table 3. *Key application weaknesses*

Type	Key issue	Impact
Data dependency [8]	Off-chain inputs	Input error risk
Contract rigidity [14-15, 32]	Code immutability	Low adaptability
System architecture [1, 5]	Off-chain storage	Integration complexity
Systemic risk [8, 30]	Shared dependencies	vulnerabilities in many projects

3.4. Vietnam contexts

The incorporation of DLT into the national construction industry is constrained by several local challenges. Building on the previously identified limitations, this section examines how global barriers are reflected in the institutional and operational context of Vietnam. The legal, technical, and organizational dimensions were selected because they help relate broader technological limitations to national conditions. Together, these dimensions provide a framework for examining the tension between immutable decentralized systems and the centralized, SME-dominated structure of the domestic sector.

The legal landscape for SC in Vietnam reflects ongoing national digitalization efforts alongside several regulatory gaps. Several national policies and legal instruments provide a foundation for digital transformation in the built environment sector. The Law on Electronic Transactions (Law No. 20/2023/QH15) recognizes digital agreements and supports the development of electronic contracts and digital signatures [12]. Decision No. 411/QD-TTg and Decision No. 749/QD-TTg promote the adoption of digital technologies across multiple domains [11, 34]. In the construction industry, Decision No. 1004/QD-BXD, issued by the Ministry of Construction, specifically supports the adoption of Building Information Modeling and broader sector digitalization [13]. Earlier, Decision No. 1255/QD-TTg marked an initial effort to develop a legal framework for the management of virtual assets and electronic money [17].

Despite supportive national strategies, several restrictions continue to hinder practical implementation. Vietnam currently lacks dedicated legislation governing SC, creating uncertainty regarding their enforceability under existing civil law [27]. Although the Law on Electronic Transactions recognizes digital agreements, enforcement still depends on centralized verification of electronic signatures. This requirement is not fully compatible with decentralized blockchain systems. In addition, current financial regulations restrict the use of cryptocurrencies, limiting payment automation to fiat-based mechanisms integrated with conventional banking infrastructure.

The implementation of SC involves several risks associated with the interaction between automated code and changing legal and project conditions. Major concerns include inaccurate data inputs, software bugs, cybersecurity threats, privacy concerns, and unclear legal responsibility during disputes [8, 16, 32]. Moreover, SC rely on off-chain data to trigger automated actions. In Vietnam, fragmented data systems increase the risk of incorrect inputs related to project progress or material quantities, which may result in erroneous payments or faulty contract execution [29]. Code immutability also limits flexibility. Errors embedded in a contract template can spread across multiple projects and are difficult to correct after deployment [30]. This creates challenges in construction projects, where schedule changes and design revisions occur frequently.

Shared blockchain infrastructure may also expose projects to broader cybersecurity risks [8]. A technical weakness in the underlying platform can affect multiple projects at the same time. In addition, legacy systems still used in smaller ASEAN projects often provide limited protection against modern digital threats [16]. Current regulations also complicate identity verification. While blockchain systems rely on decentralized identities, Vietnamese law still depends on centralized authentication [12], creating uncertainty regarding the legal accountability of project participants.

Dispute handling also remains unclear under current civil law. Existing regulations provide limited guidance on liability when payment failures result from software malfunction rather than human actions [24, 27, 32]. As shown in Table 4, these legal, technical, and operational issues continue to constrain the wider adoption of SC.

Table 4. *Specific local barriers*

Dimension	Issue	Impact
Legal	No SC-specific law [27]	Enforcement uncertainty
Legal	Centralized signature requirement [12]	Limits decentralization
Technical	Fragmented data systems [29]	Poor interoperability
Technical	Weak off-chain data [29]	Execution risk
Organizational	Resistance to change [26, 28]	Slow adoption
Organizational	Lack of expertise [26, 28]	Deployment gap

4. Proposed conceptual framework and contextual challenges

This study integrates international evidence and local constraints into a five-step adoption model, which illustrates the multi-layer implementation concept tailored for the domestic environment (Figure 2). The framework outlines a practical approach for blockchain use in the Vietnamese construction industry by aligning the technology with existing institutional conditions. Rather than pursuing full decentralization, the model introduces mechanisms to reduce legal, technical, and organizational barriers.

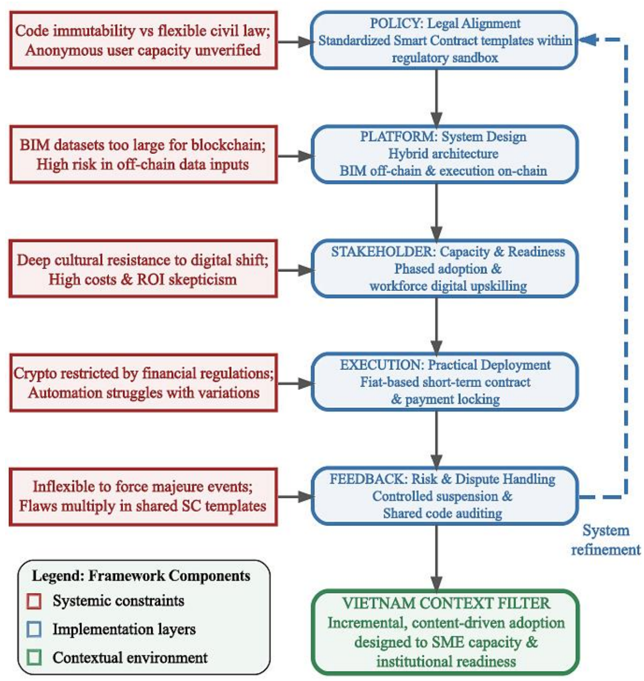

Figure 2. *Proposed smart contracts implementation framework for Vietnam*

4.1. Policy – Legal alignment

This level addresses inconsistencies between SC execution and existing legal frameworks. Code immutability conflicts with contractual provisions that permit modification under changing conditions [24], while verifying the legal status of anonymous users remains difficult [27]. To address these issues, the framework proposes standardized SC templates within a regulatory sandbox environment [25, 35]. These templates support controlled testing under regulatory supervision, while government oversight helps limit speculative activities and maintain legal compliance [9, 10].

4.2. Platform – System design

The platform focuses on data management and system integration by recommending permissioned or hybrid blockchain architecture instead of a fully public system. Because current regulations require centralized verification for digital agreements, permissioned networks allow stakeholder identities to be verified when establishing legal capacity.

The framework also adopts a hybrid architecture to address limitations in handling large BIM datasets [5]. Design data remains stored in existing centralized systems, while blockchain components manage verification and transaction logic [1, 19]. This approach combines centralized data storage with decentralized validation while maintaining regulatory and industry oversight. This setup builds on recent BIM-based digital approaches by integrating blockchain verification [36].

4.3. Stakeholder - Capacity and Readiness

This tier addresses organizational barriers to digital adoption. Many firms still lack technical expertise and clear deployment plans, while resistance to organizational change remains common [28, 29]. The framework therefore emphasizes workforce training and gradual adoption. Firms are encouraged to define objectives before deployment and adapt traditional roles to work with automated systems [31].

4.4. Execution – Practical deployment

The execution process, however, focuses on practical applications. Because financial regulations restrict the use of cryptocurrencies in Vietnam, the framework adopts a fiat-based payment mechanism integrated with the existing banking system. Initial deployment should prioritize short-term contracts with limited variation in scope and conditions [7, 15]. Payment locking and controlled fund release mechanisms may then be used to improve transaction reliability [22].

4.5. Feedback – Risk control and dispute handling

The feedback layer addresses risks associated with rigid automated execution [30]. Because SC cannot easily accommodate unexpected project changes [25], the framework incorporates a controlled suspension mechanism that allows authorized personnel to pause automated processes during disputes [18, 32]. The framework also recommends regular system audits to identify errors in shared smart contract templates before they spread across multiple projects, supported by blockchain's transparent and auditable architecture [37].

4.6. Practical use-case of automated progress payment

To demonstrate the practical application of the framework, the study proposes an automated progress payment system linked to BIM quantities [2, 19]. Figure 3 illustrates the operational data flow and actor interactions within this scenario. Under this arrangement, a SC is established between the contractor and the client, while the digital model is updated continuously with completed work quantities. Site engineers or sensors act as data oracles to provide verified project data to the platform [8, 20]. Once the centralized system confirms that a payment milestone has been achieved, the smart contract automatically transfers fiat-based payments to the contractor through the existing banking system [7, 22]. This approach reduces administrative delays and may help limit disputes by linking payments to verified construction data.

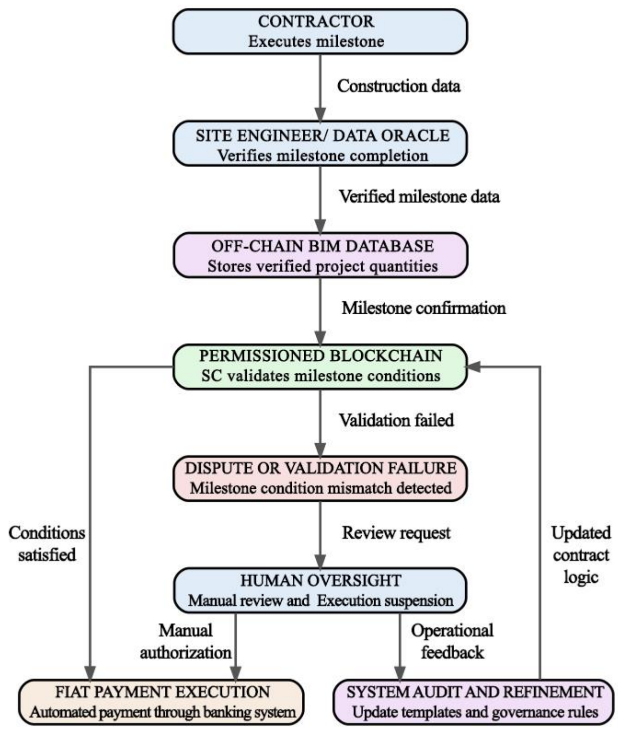

Figure 3. *Operational workflow for automated progress payments*

4.7. Implementation roadmap

Given the gap between technological potential and current institutional conditions in Vietnam, this study proposes a phased application pathway for blockchain-enabled smart contracts in the construction sector (Table 5). The framework prioritizes gradual deployment, regulatory compatibility, and organizational adaptation.

Table 5. *Sequential implementation plan for SC in construction*

Phase	Main Objectives	Key Measures
Foundation and Standardization	Establish legal and technical prerequisites	Smart contract templates, BIM data standards, legal alignment
Sandbox Pilot and Controlled Execution	Test implementation under controlled conditions	Regulatory sandbox, fiat-based payment integration, milestone verification
Capacity Building and SME Integration	Address organizational and workforce constraints	SME training, incremental deployment
Evaluation and System Refinement	Assess long-term operational performance	Reliability metrics, auditing, feedback mechanisms

5. Limitations

Although this study proposes a structured implementation pathway, several limitations remain. First, the proposed framework is conceptual and has not yet been validated through empirical case studies or pilot applications. In addition, because the analysis is primarily based on literature synthesis, some practical constraints encountered in real-world projects may not be fully addressed [10]. Similar interoperability challenges have also been identified in recent BIM-Digital Twin studies, indicating that data integration remains one of the primary barriers to advanced digital construction workflows [38]. Furthermore, the process of modifying blockchain-based solutions to fit into existing business models limits the broader potential of this technology [8, 15]. Therefore, future research should examine how local businesses can transition from constrained initial implementations.

6. Conclusion

This paper examined the adoption challenges of smart contracts in Vietnam's construction sector from legal, technical, and organizational perspectives. The findings suggest that current barriers are linked more to institutional readiness, regulatory alignment, and digital capacity than to the technology itself. To address these issues, a conceptual implementation framework, a BIM-linked payment scenario, and a staged implementation plan were proposed for the Vietnamese context. Rather than pursuing full decentralization, the approach emphasizes gradual integration under existing regulatory and operational constraints. Ultimately, future applications will fundamentally rely on clearer legal guidance, improved digital infrastructure, and workforce preparedness.

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