OPEN ACCESS

Saudi Journal of Engineering and Technology

Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Review Article

Blockchain Technology in Construction: A Systematic Review of Applications and Alignment with Nepal's Infrastructure Challenges

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DOI: https://doi.org/10.36348/sjet.2026.v11i06.001 | **Received:** 11.04.2026 | **Accepted:** 01.06.2026 | **Published:** 08.06.2026

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Abstract

Nepal's construction industry faces persistent challenges including payment delays, contract management inefficiencies, supply chain opacity, and systemic governance failures. Blockchain technology offers potential solutions through smart contracts, immutable record-keeping, and transparent shared ledgers. This paper systematically reviews blockchain applications in construction management and documented challenges in Nepal's construction sector from peer-reviewed studies. The review identifies four primary blockchain applications: smart contracts for payment automation, supply chain traceability, immutable document management, and shared transparent ledgers. Documented challenges in Nepal include payment delays (RII=0.80-0.92), contract management inefficiencies (78.6% expert agreement), low bidding averaging 37.52% below tender prices, NPR 20 billion in outstanding contractor payments, land acquisition taking 2-3 years, tree cutting approval taking 2 years, average project lag of 37 months with only 15% completed on time, and 17 National Pride Projects requiring 41 years to complete at current funding levels. Blockchain can strongly address payment delays, document coordination, supply chain tracking, and transparency. Blockchain technology offers targeted solutions for specific documented challenges in Nepal's construction sector.

Keywords: Blockchain technology, construction management, smart contracts, Nepal, payment delays, supply chain traceability, retrofitting, hydropower, corruption prevention, infrastructure governance.

1. INTRODUCTION

The construction industry is a cornerstone of Nepal's economy, contributing approximately 11% to GDP and employing the second-largest workforce after agriculture [1]. The Government of Nepal allocates 60-70% of its development budget to construction activities [2]. However, construction projects in Nepal consistently face severe performance challenges.

1.1 General Construction Delays

A systematic review of construction delays in Nepal found that technical issues and lack of construction materials, equipment, and manpower are the most common delay factors, each appearing in 83.33% of reviewed studies. Low bidding of contracts, unrealistic contract durations, and political issues each appeared in 66.67% of reviewed studies [3]. According to the Asian Development Bank, the average lag in public construction industries in Nepal was 37 months, and only 15% of tasks were completed within the desired time frame [3].

1.2 Retrofitting Project Delays

In retrofitting of public buildings in Kathmandu Valley, all 11 projects analyzed experienced significant delays beyond planned completion timelines. The maximum recorded delay was 167% time overrun, while the minimum was 42%. Only one project achieved physical progress of 22%. Top-ranked delay factors included impractical project schedule and duration (RII=0.775), unavailability of skilled workforce (RII=0.766), lack of coherence in architectural, structural, electrical, sanitary, and HVAC drawings (RII=0.742), approvals of shop drawings (RII=0.717),

and unavailability of specific materials as per BOQ (RII=0.717) [17].

1.3 Hydropower Project KPIs

In small hydropower projects (10-25 MW capacity), stakeholders ranked cost as the most important KPI (average score 70.10), followed by time (61.82) and quality (58.87). Hypothesis tests revealed significant differences between client-consultant ($p=0.00183$), client-contractor ($p=0.00150$), and consultant-contractor ($p=0.00132$) rankings. For KPI-Cost, the most affecting factor was cost of rework (RII=0.579). For KPI-Time, delay in approval of updated programme by contractors (RII=0.508) was most critical. For KPI-Quality, quality-related training and meetings (RII=0.523) was most important. For KPI-Client Satisfaction, number of reworks and speed of service to owner (RII=0.513) were most important [15].

1.4 Supply Chain and Material Management

Comparative analysis of supply chain management in public and private building construction (Cronbach's alpha=0.926) found that public sector faces barriers including delay in delivery/inferior quality materials (RII=0.767) and cost of material (RII=0.750). Private sector faces delay in payment (RII=0.822) and cash to cash cycle (RII=0.767) [14].

1.5 Systemic Inefficiencies in Large-Scale Projects

Analysis of 10 International Competitive Bidding (ICB) projects revealed eight systemic challenges: bureaucratic red tape (a single road project may require clearance from up to 17 agencies), lack of transparency and corruption, delay in payment to contractors (NPR 20 billion outstanding), vendor lock-in and monopolistic procurement, interdepartmental coordination failures, time delays and budget overruns, political interference and instability, and inadequate capacity building [2].

The World Bank's analysis reveals that land acquisition takes 2-3 years on average due to outdated valuation methods, fragmented records, and frequent compensation disputes. Tree cutting approval processes take 2 years on average. At current funding levels, completing 17 National Pride Projects would take 41 years [5].

1.6 Contract Management Inefficiencies

In rural road projects, 78.6% of experts agreed there are significant inefficiencies in contract management practices. Key challenges included lack of cooperation and proper communication between client, consultant, and contractor (mean=1.86 on a 1-5 scale), lack of monitoring and evaluation (mean=1.98), delay in construction work within intended completion date (mean=1.50), slow decision-making (mean=1.74), and improper planning and poor site management (mean=1.33) [6].

1.7 Payment Delay Analysis

Payment delay analysis revealed that "unavailability of budget" was ranked as the top cause by both employers (RII=0.80) and contractors (RII=0.92). Other factors included employer's poor financial management (employer RII=0.74, contractor RII=0.81), contractor's failure to understand contract agreement (employer RII=0.86), and price escalation (contractor RII=0.76). Hypothesis testing revealed significant differences between employer and contractor views ($p<0.05$ for all three categories: attributable to employer, attributable to contractor, and beyond party's control) [7].

1.8 Extension of Time (EoT) Causes

Principal Component Analysis on 25 EoT causes (KMO=0.935) identified three components. Component 1 (Design and Consultant-Related Issues, Eigenvalue=13.892, 55.57% variance) included insufficient information exchange in design phase (loading=0.740) and insufficient information in drawings (0.726). Component 2 (Project Management and Execution Challenges, Eigenvalue=1.146, 4.58% variance) included ineffective quality control (0.839). Component 3 (External and Unforeseen Conditions, Eigenvalue=1.000, 4.00% variance) included land acquisition disputes (0.776) [9].

1.9 User Committee Performance Issues

Exploratory Factor Analysis (KMO=0.753, Bartlett's test $\chi^2=566.857$, df=36, $p=0.000$) revealed high loadings for payment procedure (0.932), transparency maintained (0.882), timely monitoring and supervision (0.923), and project bookkeeping (0.823) [12].

1.10 Risk Factors in Bridge Construction

Thirty-nine common risk factors contributing to time delay and cost overruns in bridge construction projects were identified, including design changes, unforeseen site conditions, regulatory problems, inadequate project management practices, and poor coordination among stakeholders [8].

1.11 Blockchain as an Emerging Solution

Blockchain technology has been proposed as a solution to construction management challenges [11,13]. Key features include immutability (records cannot be altered after verification), decentralization (no single point of control), transparency (all authorized parties access the same data), smart contracts (self-executing code when conditions are met), and traceability (complete history of transactions) [13]. Simulated blockchain-enhanced project management systems demonstrated a 33% reduction in transaction time, reduction in error rate from 15% to 2%, and elimination of payment discrepancies compared to traditional systems [13].

This paper systematically reviews blockchain applications and Nepal's construction challenges to identify alignment and research gaps.

2. Experimental Section

This paper employs a systematic literature review approach following established guidelines for construction management research [13]. The search was conducted across Scopus, Google Scholar, and NepJOL databases for publications between 2017 and 2026. Search terms included "blockchain construction," "smart contracts infrastructure," "construction delays Nepal," and "infrastructure project management Nepal."

Inclusion criteria required that papers be peer-reviewed, published between 2017 and 2026, focus on construction or infrastructure, and be written in English. The final sample included papers on blockchain in construction and papers on construction challenges in Nepal.

3. RESULTS AND DISCUSSION

3.1 Documented Construction Challenges in Nepal

Challenge Category	Key Finding	Source
General delays	37 months average lag, 15% on-time completion	[3]
Retrofitting delays	Max 167% overrun, impractical schedule RII=0.775	[17]
Hydropower KPIs	Cost ranked 1st (70.10), significant stakeholder disagreement	[15]
Supply chain (public)	Material delivery delay RII=0.767	[14]
Supply chain (private)	Payment delay RII=0.822, cash to cash cycle RII=0.767	[14]
Systemic inefficiencies	8 challenges, 17 agencies for one project	[2]
World Bank	Land acquisition 2-3 years, 41 years for 17 projects	[5]
Contract management	78.6% expert agreement on inefficiencies	[6]
Payment delays	Employer RII=0.80, contractor RII=0.92	[7]
EoT causes	Design issues 55.57% variance, KMO=0.935	[9]
User committees	Payment procedure loading=0.932, transparency=0.882	[12]
Bridge risks	39 risk factors identified	[8]

3.2 Blockchain Applications in Construction

Application	Key Feature	Key Studies
Smart contracts	Automatic payment upon milestone completion	[11,13]
Supply chain traceability	Provenance tracking from source to site	[14,15]
Immutable document management	Tamper-proof records, audit trails	[16]
Shared transparent ledger	Real-time data access for all stakeholders	[13]

3.3 Alignment Analysis

Strong Blockchain Alignment:

Payment delays (RII=0.80-0.92, NPR 20 billion outstanding) can be addressed through smart contracts [13]. Lack of communication (mean=1.86) can be addressed through shared transparent ledgers [13]. Insufficient information exchange in design phase (loading=0.740) can be addressed through immutable document version control [16]. Material delivery delays (RII=0.767) can be addressed through supply chain traceability [14,15]. Lack of transparency (loading=0.882) can be addressed through immutable shared ledgers [13]. Payment procedure in User Committees (loading=0.932) can be automated via smart contracts [12].

Moderate Alignment:

Bureaucratic red tape, time delays (37 months average lag), land acquisition delays (2-3 years), and approval processes (2 years for tree cutting) can be partially addressed through blockchain tracking and land registries.

No Alignment:

Political interference, inadequate qualifications (loading=0.735), capacity building, unforeseen ground conditions (loading=0.768), and climate change fall outside blockchain's scope, requiring governance reform and human resource development.

4. CONCLUSION

This paper systematically reviewed blockchain applications in construction and documented challenges in Nepal's construction sector from peer-reviewed studies including retrofitting delays, hydropower KPIs, supply chain management, contract inefficiencies, payment delays, EoT causes, user committee issues, and systemic governance failures.

Key Findings:

- Nepal's construction sector faces severe challenges: payment delays (RII=0.80-0.92), bids averaging 37.52% below tender, NPR 20 billion outstanding, land acquisition taking 2-3 years, tree cutting approval taking 2 years, 37 months average project lag with only 15% on-time completion, 17 National Pride Projects requiring 41 years, retrofitting delays up to 167%, and significant stakeholder disagreement on KPI priorities
- Blockchain offers four primary applications: smart contracts, supply chain traceability,

immutable document management, and shared transparent ledgers
- Strong alignment exists for payment delays, document coordination, supply chain tracking, and transparency
- Moderate or no alignment exists for political interference, HR issues, and climate change

Recommendations:

For policymakers:
- Pilot blockchain for payment automation in government projects, starting with User Committee projects (payment procedure loading=0.932)
- Amend the Electronic Transactions Act to recognize smart contracts
- Establish a Construction Payment Guarantee Fund

For construction stakeholders:
- Prioritize blockchain for supply chain tracking (material delivery delay RII=0.767)
- Implement blockchain-based document management (design information exchange loading=0.740)
- Use smart contracts for milestone-based payments (payment delay RII=0.80-0.92)

For researchers:
- Conduct stakeholder perception surveys and legal analysis
- Implement pilot studies in retrofitting, hydropower, and road projects

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