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Blockchain & AI Integrated Framework for Predictive and Secure Quantum Construction Project Management

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1. Abstract

The construction industry continues to face problems such as budget overruns, project delays, and poor data management.

These issues mostly arise from disconnected systems, manual workflows, and the lack of real-time decision-making.

This study introduces a combined framework that merges Artificial Intelligence (AI) with Blockchain technology to address these challenges.

AI is used to predict potential project risks, delays, and cost fluctuations, while Blockchain ensures secure, transparent, and tamper-proof data management. The framework improves collaboration among project participants, improves forecast accuracy, and increases data reliability. The findings show that the combination of these technologies can greatly improve project outcomes and provide a scalable solution for modern construction management.

2. Keywords

Blockchain, Artificial Intelligence, Construction Project Management, Predictive Analytics, Smart Contracts, Data Security.

3. Introduction

The construction industry is essential for economic growth, but it often faces challenges related to inefficient project management.

Many projects exceed budgets by 10% to 30% and face delays of up to 50% beyond initial schedules. These problems are mostly due to poor coordination, lack of integrated data systems, and reliance on manual decision-making.

Traditional project management techniques are no longer sufficient for the complexities of modern construction.

As projects grow larger and involve more stakeholders, there is a growing need for systems that support real-time decision-making, predictive analytics, and secure data sharing.

New technologies like AI and Blockchain offer potential solutions.

AI can analyze large datasets to perform predictive analytics, while Blockchain provides transparency, traceability, and security through its decentralized nature. However, the combined use of these technologies in construction project management is still limited. This research aims to develop a unified framework using both technologies to improve the efficiency and reliability of construction projects.

4. Literature Review

Existing studies highlight the growing importance of digital technologies in managing construction projects.

AI-based systems have been found effective in improving cost estimation, scheduling accuracy, and risk assessment. At the same time, Blockchain technology enhances transparency, reduces conflicts, and enables secure data exchange through decentralized networks.

Research also shows the potential of smart contracts to streamline payment processes and reduce delays in contractual procedures.

Digital tools such as Building Information Modeling (BIM), the Internet of Things (IoT), and real-time data

analysis also play an important role in improving coordination and oversight in construction.

Despite these technological advances, much of the current research remains theoretical, with limited real-world applications.

There is a notable gap in creating a comprehensive framework that combines predictive analytics with secure data management. This gap forms the basis of the current study.

5. Methodology

The research uses a mixed-method approach that includes both quantitative and qualitative methods.

Primary data was collected through a structured survey using a five-point Likert scale. A total of 80 responses were considered sufficient based on statistical sampling criteria.

The data was analyzed using percentage analysis and the Relative Importance Index (RII) to identify the key factors affecting project performance.

Additionally, expert validation was conducted to ensure the reliability and practical applicability of the results.

❖ **Questionnaire Design**

- Total Questions: 35
- Type: Close-ended (Likert Scale)
- Options:
  - Strongly Disagree (1)
  - Disagree (2)
  - Neutral (3)
  - Agree (4)
  - Strongly Agree (5)

❖ **Survey Method Steps**

(As per Scope Criteria)

- Selection of research method and formula
  - Preparation of structured questionnaire
  - Internal review by faculty members
  - Validation by three experts
  - Necessary corrections and finalization
  - Data collection through survey
  - Data analysis using statistical methods
  - Final validation by external experts

❖ **Sample Size Determination**

Sample size was decided using standard statistical formula:

$$n = \frac{Z^2 \cdot p \cdot q}{e^2}$$

Where:

- **Z = 1.96** (95% confidence level)
- **p = 0.5**
- **q = 0.5**
- **e = 0.11 (acceptable error)**

❖ **Sample Size Calculation**

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.11)^2} = \frac{3.8416 \times 0.25}{0.0121}$$

$$n = \frac{0.9604}{0.0121} = 79.37 \approx 80$$

Note: - minimum 80 Response is Required.

Collected 109 Responses through the Question answer Done with Construction employees and users who faces problem in same domain.

6. Proposed Framework

The suggested framework merges AI and blockchain into a cohesive system for managing construction projects. It comprises three main components:

Data Layer: -This layer focuses on the gathering and storage of project-related information including costs, schedules, resources, and contracts.

AI Layer: -This involves the use of predictive models to ascertain potential delays, cost overruns, and risks based on both historical and real-time data.

Blockchain Layer: -This component features a secure and decentralized data storage system that guarantees transparency, immutability, and trust among all stakeholders. Smart contracts facilitate the automation of transactions and approvals.

This integrated system allows for real-time oversight, enhances decision-making, and ensures secure collaboration among all project stakeholders.

7. Analysis and Discussion

The evaluation relies on data gathered through a well-organized questionnaire that utilized a five-point Likert scale. The analysis employed the Relative Importance Index (RRI) method to pinpoint the most significant factors influencing the performance of construction projects.

The findings reveal that several critical issues consistently affect project results. Factors such as inefficiencies in planning, delays in procurement, poor interdepartmental coordination, and financial holdups were identified as having elevated RRI values, indicating they have a substantial impact on project outcomes. Notably, delays in decision-making and the lack of predictive systems emerged as significant causes of budget overruns and extended timelines.

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The visual representation of the findings clearly illustrates the hierarchy of these factors according to their relative significance. The highest-ranked factors underscore the necessity for enhanced integration among planning, execution, and financial operations. These insights reinforce the notion that conventional systems tend to be reactive and do not sufficiently preempt issues before they escalate.

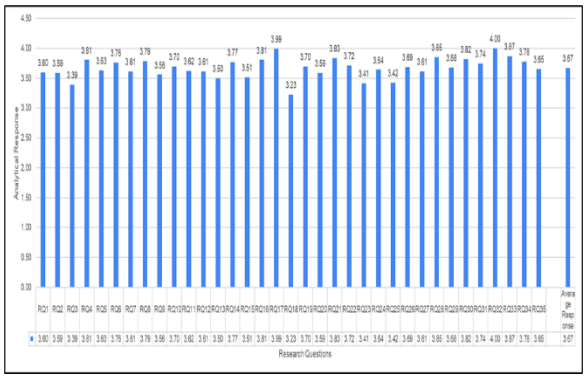

Fig-7.1. Bar chart of Questionnaire Survey Analytical Response

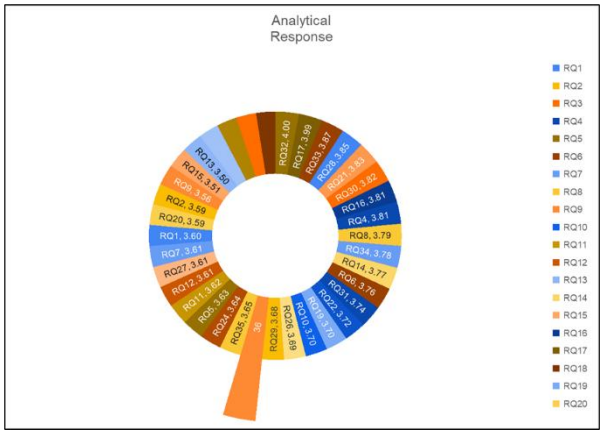

Fig-7.2. Sunburst chart of Analytical Response

❖ **Percentage of achievement**

The analysis of validated survey data shows an overall achievement level of **73.43%,** showing that current construction management systems are moderately effective.

While existing practices in planning, billing, & coordination are functional, they are not fully perfected for modern project demands. The results highlight notable gaps & inefficiencies in execution & integration. Expert validation also confirms the reliability of these findings.

Therefore, there is a clear need to adopt advanced solutions like a **Blockchain and AI integrated framework** to improve efficiency, transparency, & project performance.

$$\text{Total Percentage} = \frac{\text{Percentage of Average Response}}{peack\ Response} X100$$

$$= \frac{3.67}{5} X100$$

$$= 73.43\%$$

❖ **Relative Importance Index (RRI) Analysis**

The Relative Importance Index (RRI) is a statistical tool used to decide the relative significance of a range of factors based on respondent's opinions. It is widely used in construction management research to rank parameters such as planning efficiency, cost control, coordination, & technology's adoption.

In this study, RRI is used to analyze responses collected through an organised questionnaire based on a five-point Likert scale.

The method helps in converting qualitative beliefs into quantitative values, enabling effective comparison & prioritization of key factors influencing construction project management.

➢ **RRI Formula**

$$RRI = \frac{\sum W}{A \times N}$$

Where:

- **W** = Weight assigned to each response (1 to 5)
- **A** = Highest weight (5)
- **N** = Total number of responses.

➢ **Expanded Formula (Used in Calculation)**

$$RRI = \frac{(5 \times n_5) + (4 \times n_4) + (3 \times n_3) + (2 \times n_2) + (1 \times n_1)}{5 \times N}$$

Where:

- n_5= Strongly Agree
- n_4= Agree
- n_3= Neutral
- n_2= Disagree
- n_1= Strongly Disagree

➢ **RRI Calculation Table**

Response Category	Weight	Count	Weighted Value
Strongly Disagree	1	347	347
Disagree	2	364	728
Neutral	3	653	1959
Agree	4	1283	5132

Strongly Agree	5	1168	5840
Total	N	**3815**	**14006**

Table 5: - RRI Computation Table

➢ **Final Calculation**

$$RRI = \frac{14006}{5 \times 3815}$$
$$= \frac{14006}{19075} =$$
$$= 0.734$$

=73.4%

➢ **RRI Conclusion and Interpretation**

The calculated Relative Importance Index (RRI) value is **0.734 (73.4%)**, which shows a **prominent level of agreement** among respondents about the factors considered in this study.

This value suggests that:

1. Most respondents have a **positive feeling** toward the identified issues.
2. Key challenges such as planning inefficiencies, cost overruns, and coordination gaps are **significantly affecting construction projects.**
3. There is a strong inclination toward the **adoption of advanced technologies** such as Artificial Intelligence and Blockchain for improving project performance.

➢ **Interpretation Scale**

- **0.80 – 1.00** → Very High Importance
- **0.60 – 0.80** → High Importance
- **0.40 – 0.60** → Moderate Importance
- **Below 0.40** → Low Importance

Since, **0.734 or 73.4% falls in High Importance**, the factors studied are considered **critical and influential** in construction project management.

The suggested framework offers a systematic method by merging predictive analytics with secure data management. By leveraging Artificial Intelligence, potential risks related to time and costs can be identified early on, while blockchain technology guarantees that all project data remains secure, transparent, and resistant to tampering. This combination fosters greater trust among stakeholders and minimizes the chances of conflicts.

Additionally, integrating systems across various departments improves communication and mitigates delays caused by disjointed workflows. The findings indicate that a cohesive digital framework can greatly enhance decision-making and overall project effectiveness.

Nevertheless, the adoption of such systems may encounter obstacles, including the need for initial capital investment, the requirement for technical skills, and resistance to embracing new technologies. Despite these renderings, the results suggest that the long-term benefits regarding efficiency, transparency, and dependability render the proposed framework a practical solution for contemporary construction project management.

8. Conclusion

This study illustrates that the integration of Artificial Intelligence and Blockchain can markedly improve the management of construction projects. The proposed framework tackles essential concerns related to cost, time, and data security by offering a structured and technology-oriented solution.

The results indicate that the implementation of such integrated systems can enhance efficiency, decrease delays, and foster better coordination among stakeholders. Future studies should concentrate on the practical application and performance assessment of the framework in extensive construction projects.

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