Blockchain in Project Management

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Abstract

Project management involves organizing resources and activities to achieve specific objectives within time and budget. However, conventional project management methods can be inefficient, error-prone, leading to communication challenges and disputes. This research paper proposes new framework called Smart Contract Project Management Framework (SCPMF) and explores the advantages and obstacles associated with implementing it, combining Rule Engines and blockchain technology to improve project management transparency, accountability, and security. The paper provides an overview of SCPMF and its applications in project planning, resource management, and contract management while discussing the benefits and challenges of implementing SCPMF in project management. The paper concludes by explained the limitations in future research and highlights the potential of SCPMF to revolutionize project management.

Keywords— Smart Contract, Project Management, Real-Time Monitoring, Automated Contract Execution, Immutable Record-Keeping, Blockchain, Rule Engine, Smart Contracts.

Introduction

Effective project management is essential for completing projects in diverse sectors (Kerzner, 2018). It involves the application of knowledge, skills, tools, and techniques to meet project requirements and achieve project objectives within defined constraints (Project Management Institute, 2017). Effective project management enables organizations to plan, execute, and control projects systematically and efficiently, ultimately achieving desired outcomes. The field of project management has evolved significantly over the years, driven by technological advancements, changing business dynamics, and the increasing complexity of projects. Today, project management encompasses various industries, including construction, information technology, healthcare, manufacturing, and more (Müller & Turner, 2019). However,

regardless of the industry, project management's fundamental principles and best practices remain consistent, focusing on delivering projects on time, within budget, and to stakeholders' satisfaction (Kerzner, 2018).

Any project's success relies heavily on managing various aspects, including scope, time, cost, quality, resources, risks, and communication (Project Management Institute, 2017). Project managers are responsible for planning, organizing, and controlling these elements to ensure success. They must possess a diverse skill set that enables them to lead cross-functional teams, make informed decisions, manage conflicts, and adapt to changing circumstances (Project Management Institute, 2017). In addition to traditional project management approaches, new technologies have significantly impacted the field. One such technology that has gained significant attention is blockchain. Originally introduced as the underlying technology for cryptocurrencies like Bitcoin, blockchain has demonstrated its potential to revolutionize various industries, including project management (Swan, 2015).

Blockchain technology provides a decentralized, transparent, and secure platform for recording and verifying transactions (Nakamoto, 2008). It creates a distributed ledger that multiple parties can access and update, eliminating the need for intermediaries and providing a tamper-proof record of all transactions (Nakamoto, 2008). This technology can transform project management by enhancing transparency, improving accountability, reducing fraud, and increasing efficiency (Drescher, 2017).

In recent years, researchers and practitioners have explored the application of blockchain technology in project management (Müller & Wüst, 2018). By leveraging blockchain, project managers can benefit from enhanced data security, improved stakeholder collaboration, streamlined processes, and automated execution of smart contracts (Zheng et al., 2017). Smart

contracts, self-executing digital contracts coded with predefined rules and conditions, can automate various project management processes, such as contract administration, payment processing, and milestone tracking (Szabo, 1997).

While the potential of blockchain technology in project management is promising, some challenges and considerations need to be addressed. These include scalability, interoperability with existing systems, legal and regulatory implications, and the need for technical expertise (Böhme et al., 2015). Research and development efforts are underway to overcome these challenges and unlock the full potential of blockchain in project management (Bogner et al., 2019). This paper aims to provide a comprehensive overview of project management, including its principles, processes, challenges, and opportunities. In addition, it will explore the application of blockchain technology in project management and discuss the benefits, limitations, and prospects of integrating blockchain into project management practices. The findings of this study will contribute to the growing body of knowledge on blockchain in project management and provide insights for practitioners and researchers alike.

Problem Statement

The construction industry is a vital sector that contributes significantly to global economic growth (Mandzuk & Ruikar, 2020). However, it is notorious for project delays, cost overruns, and disputes, leading to significant losses and negative stakeholder impacts (Wang et al., 2020). The traditional project management approach, which relies heavily on manual processes, often fails to address these challenges effectively. Lack of transparency, communication, and trust among stakeholders are vital issues affecting project management in the construction industry (Odeh & Battaineh, 2021).

Blockchain technology has emerged as a smart solution to these challenges. Blockchain technology offers unique features such as decentralization, immutability, and intelligent contract automation, which can improve transparency, data management, collaboration, and trust among project stakeholders (Wang et al., 2020). However, implementing blockchain technology in the construction industry is not without challenges. According to Mandzuk and Ruikar (2020), a significant challenge in adopting blockchain technology in project management is insufficient stakeholder awareness and comprehension. Additionally, the lack of standardization and interoperability of different blockchain platforms and the limited scalability of blockchain technology are significant challenges that need to be addressed (Odeh & Battaineh, 2021). Furthermore, managing complex projects often involves multiple stakeholders with different roles and responsibilities, leading to communication challenges and potential disputes (Wang et al., 2020). Furthermore, traditional project management methods often rely on manual interventions, which can be inefficient and prone to errors (Odeh & Battaineh, 2021).

Objective

The main objective of this research project is to increase the adoptability of blockchain technology in project management by addressing the challenges faced in traditional project management and promoting the standardization of project management practices within the blockchain context. This will be achieved by enhancing stakeholders' awareness and understanding of blockchain technology, providing guidelines and best practices for implementing project management processes within the blockchain ecosystem, introducing the Smart Contract Project Management Framework (SCPMF) as a solution, and offering implementation guidance for organizations. The project also aims to foster collaboration and knowledge sharing among project management professionals, researchers, and industry experts to facilitate the exchange of insights and experiences in utilizing blockchain for project management. By achieving these objectives, this research project aims to contribute to the broader adoption of blockchain technology in project management, enhancing transparency, efficiency, and trust in project execution while delivering valuable insights for practitioners and researchers in the field.

Blockchain Technology

Blockchain technology has emerged as a transformative innovation with the potential to revolutionize various industries, including project management in the construction sector. The concept of blockchain originated with the introduction of Bitcoin, a decentralized digital currency, in 2008 by an anonymous person or group known as Satoshi Nakamoto (Nakamoto, 2008). Blockchain technology was initially designed as a secure and transparent ledger system to record and verify Bitcoin transactions without the need for intermediaries, such as banks or governments. At its core, blockchain is a distributed ledger that operates on a network of computers, known as nodes, where each node stores an identical copy of the blockchain. The blockchain consists of a

series of blocks, each containing a list of transactions (Ammar, 2019). These transactions are grouped, verified, and added to the blockchain through a consensus mechanism, such as proof of work or proof of stake.

The real potential of blockchain lies in its ability to provide a decentralized, transparent, and secure platform for recording and verifying various types of transactions and data. By eliminating the need for intermediaries and central authorities, blockchain technology offers a trustless environment where participants can interact directly, reducing the reliance on third parties and enhancing transparency and accountability (Majumder, 2019). As a result, blockchain technology can offer several benefits in the construction industry, where project delays, cost overruns, and disputes are common challenges. One of the key advantages is increased transparency, as all stakeholders can have real-time access to project information, including contracts, payment records, and project progress. This transparency reduces information asymmetry and fosters stakeholder trust (Zhang et al., 2020).

Furthermore, blockchain can streamline processes and reduce inefficiencies by automating tasks using smart contracts. Smart contracts are self-executing digital contracts that contain predefined rules and conditions. They automatically execute transactions and trigger actions when specific conditions are met, eliminating the need for manual intervention, and reducing the potential for human error (Wang et al., 2020). Another significant advantage of blockchain in the construction industry is improved data security. Blockchain's decentralized nature and cryptographic algorithms make it highly resistant to tampering and fraud. In addition, data stored on the blockchain is distributed across multiple nodes, making it difficult for malicious actors to manipulate or alter the information. This enhanced security can protect sensitive project data and mitigate the risk of data breaches (Zhang et al., 2020). As blockchain technology continues to

evolve, its future capabilities are poised to expand further. One area of development is the integration of blockchain with other emerging technologies, such as the Internet of Things (IoT) and artificial intelligence (AI). The combination of blockchain, IoT, and AI can automate data collection, analysis, and decision-making processes in construction projects, leading to increased efficiency and optimized resource utilization (Wang et al., 2020).

Moreover, ongoing research and development efforts are focused on addressing blockchain's scalability and interoperability challenges, which currently limit its widespread adoption. Solutions such as sharding, sidechains, and layer two protocols aim to enhance the capacity and speed of blockchain networks, enabling them to handle a higher volume of transactions and support complex applications (Swan, 2015). Blockchain technology can potentially transform project management in the construction industry by improving transparency, streamlining processes, enhancing data security, and fostering trust among stakeholders. Its ability to automate tasks through smart contracts and provide a tamper-proof and decentralized data storage and verification platform holds significant promise. With further advancements and the integration of complementary technologies, blockchain's future capabilities in project management are likely to expand, enabling more efficient and collaborative construction projects.

Blockchain in Project Management

The construction industry has attracted significant attention in research as a potential beneficiary of blockchain technology for improving project management. Researchers have proposed various frameworks and systems that leverage blockchain technology to address the industry's challenges and enhance efficiency. One example is the framework Ginzburg (2020) suggested, which combines blockchain with Building Information Modeling (BIM). By integrating blockchain technology with BIM, project management efficiency can be improved, and

construction disputes can be reduced. In addition, the transparency and immutability of blockchain can enhance collaboration and trust among project stakeholders by providing a secure and reliable platform for sharing and accessing project information. Another proposal by Korkmaz and Arditi (2019) introduces a decentralized platform that utilizes blockchain for information exchange and contract execution among project stakeholders. By leveraging blockchain's distributed ledger technology, the platform can facilitate secure and transparent communication, streamline contract processes, and reduce reliance on intermediaries. This decentralized approach can enhance project management efficiency and minimize the risk of disputes.

Iyer and Gupta (2020) proposed an Intelligent Contracting System that utilizes smart contracts to automate contract administration processes in the construction industry. By leveraging the programmable nature of smart contracts, routine tasks such as payment processing, milestone tracking, and change order management can be automated, reducing manual intervention and the potential for errors. This automation can enhance project management efficiency and streamline contract administration. Building upon these existing proposals, our research paper presents a framework for the negotiation and execution of smart contracts using blockchain technology in the construction industry. The framework incorporates various features, including access controls, privacy, and security, to ensure the efficient and secure management of construction projects.

Furthermore, by utilizing a permissive private blockchain network, we aim to enhance collaboration and efficiency while minimizing the risk of disputes. The integration of blockchain technology into the construction industry offers several potential benefits. Firstly, it can improve project management efficiency by automating contract processes, streamlining communication, and enabling real-time project progress tracking. Furthermore, this automation reduces the reliance on manual processes, improves accuracy, and accelerates project timelines.

Secondly, blockchain technology can minimize conflicts by providing a transparent and immutable record of project data and transactions. This transparency reduces the potential for disputes, and fosters trust among project stakeholders. Additionally, the decentralized nature of blockchain removes the need for intermediaries, reducing the likelihood of discriminatory or unfair practices. However, it is essential to note that while the potential benefits of integrating blockchain technology into the construction industry are promising, additional research is needed to understand and realize these advantages fully. Further studies can explore scalability, interoperability, and regulatory considerations to ensure the successful implementation of blockchain-based solutions in the construction industry.

Methodology

The proposed Smart Contract Project Management Framework (SCPMF) development involved several stages, including requirements gathering and conceptual design (Korkmaz & Arditi, 2021; Samper-Zapater et al., 2020; Wang et al., 2020). The methodology used to develop the SCPMF was an iterative approach that involved continuous feedback and refinement of the framework. The implementation of the SCPMF was not covered in this research paper. The methodology used for requirements gathering involved identifying the typical project stages in project management and the challenges faced by stakeholders in the construction industry (Korkmaz & Arditi, 2021; Samper-Zapater et al., 2020; Wang et al., 2020). The conceptual design involved the creation of smart contracts for each project stage and the integrating of a Rule Engine to execute the contracts automatically. The SCPMF also utilized several distributed databases in the blockchain network, such as vendor distributed database, contractor-distributed database, and other related shareable distributed databases.

The SCPMF will be designed using tools and programming languages, including Solidity for innovative contract development, Node.js for server-side scripting, and React for the user interface (Korkmaz & Arditi, 2021; Samper-Zapater et al., 2020; Wang et al., 2020). Solidity is one of the programming languages for creating smart contracts with the help of the Ethereum blockchain. Node.js is a platform that allows for creating server-side applications using JavaScript. Finally, the React library is a JavaScript library for constructing user interfaces.

Proposed Smart Contract Project Management Framework

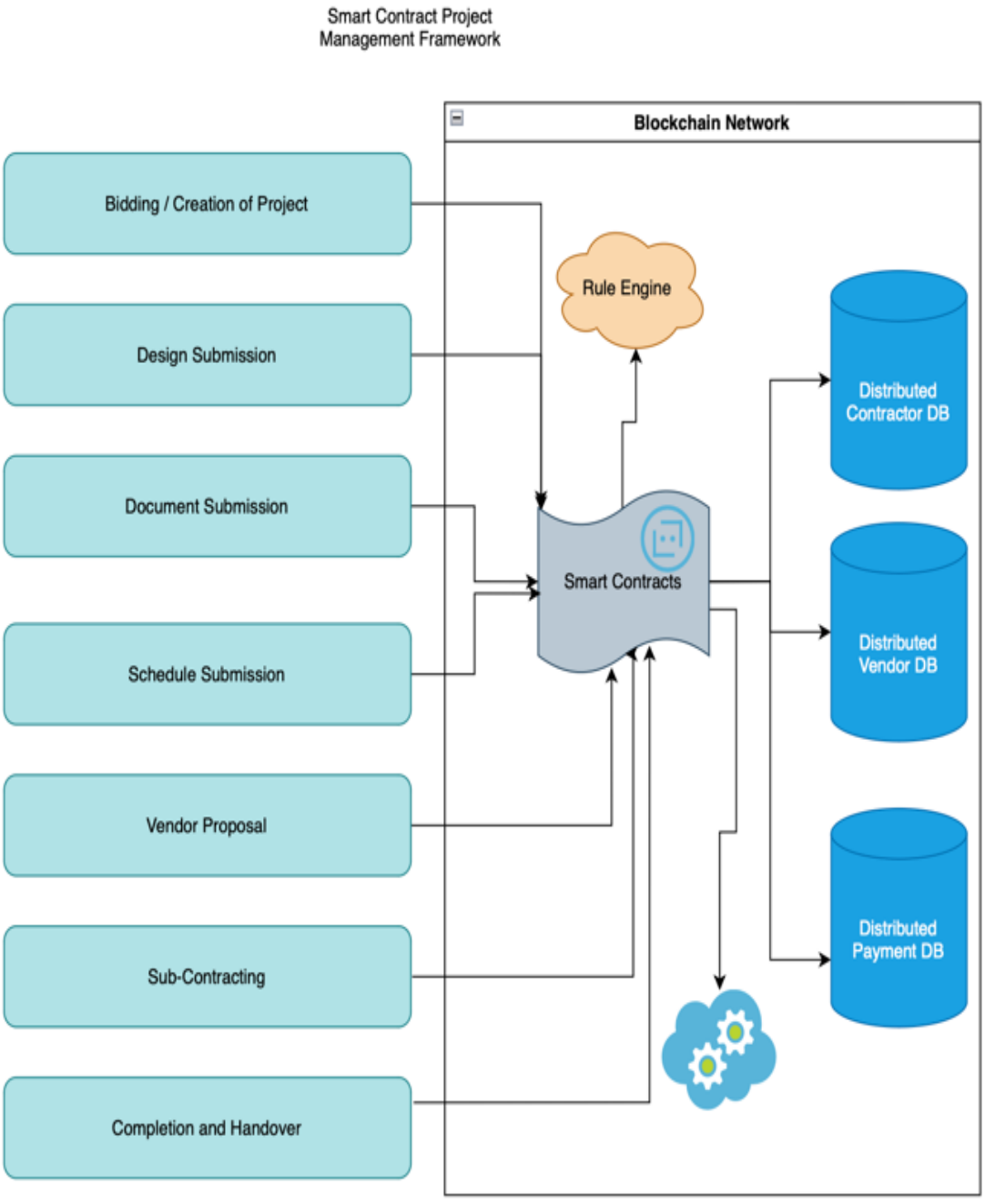
Project management involves coordinating various stakeholders and resources to achieve project goals within constraints such as time, budget, and scope (Kerzner, 2018). Using SCPMF in project management could significantly improve project outcomes by streamlining project processes and increasing project efficiency (Wang et al., 2021). However, the implementation of SCPMF in project management is not without challenges. One of the main challenges is the scalability of blockchain technology, which limits the number of transactions that can be processed per second (Zohrevandi & Arora, 2021). Another challenge is the interoperability of different blockchain platforms, which can hinder the integration of SCPMF with existing project management systems (Gulmez & Kocaman, 2021). Furthermore, regulatory compliance is a key concern when using blockchain technology, as the legal status of smart contracts varies across different jurisdictions (Cocco et al., 2020).

Smart Contract Project Management Framework (SCPMF) is a proposed conceptual model that combines intelligent contract technology with project management principles to enhance project management transparency, accountability, and security. This framework has the potential to revolutionize project management by enabling real-time monitoring of project progress, automated contract execution, and immutable record-keeping (Gai et al., 2018; Botta et al., 2019).

Blockchain technology has been selected as a critical enabler for SCPMF because it ensures trust, security, and efficiency in project management. The benefits of blockchain technology in project management include enhanced transparency, accountability, and security. Additionally, blockchain technology can address the limitations of traditional project management approaches' limits and improve project management processes' efficiency (Alqerm & Al-Husban, 2021).

Figure 1

The proposed Smart Contract Project Management Framework in Construction Industry



The proposed SCPMF identifies all standard project stages in project management and creates smart contracts whenever someone initiates the process, and then these contracts are automatically executed using a Rule Engine (Farooq et al., 2020). A Rule Engine is a software tool used to maintain and execute rules. It is designed to automatically apply the appropriate rule(s) to a given data set based on the defined criteria.

In SCPMF, the Rule Engine maintains various rules to execute smart contracts when specific criteria are met. For example, if a contract states that a particular task must be completed by a deadline, the Rule Engine would monitor the task's progress and trigger the execution of the smart contract when the deadline is approaching (Jiang et al., 2020). In SCPMF, a Rule Engine guarantees the automatic and timely execution of smart contracts, thereby decreasing the need for human intervention and mitigating the potential for disputes. To implement SCPMF, various programming frameworks are available, such as Ethereum, Hyperledger Fabric, and Corda. Ethereum is an open-source blockchain platform that enables the development of decentralized applications using smart contracts. Hyperledger Fabric is a private blockchain platform that allows multiple organizations to collaborate on a single project. Corda is a distributed ledger technology platform for enterprise use, allowing secure and confidential transactions among various parties (Schoenherr et al., 2019).

In SCPMF, intelligent contracts are integrated with many distributed databases in blockchain, such as vendor-distributed databases, contractor-distributed databases, and other related shareable distributed databases. This integration allows all stakeholders to access relevant project data based on their roles, ensuring that sensitive data remains private and secure (Jiang et al., 2020). Moreover, this integration enhances collaboration and trust among stakeholders. All

parties can view and track project progress in real-time, reducing the chances of disputes and improving overall efficiency.

Smart Contracts

Smart contracts are self-executing computer programs that enable the automatic enforcement of contract terms, providing a reliable mechanism for executing contractual obligations. They are typically stored on a blockchain platform, ensuring secure and transparent execution of the contract without the need for intermediaries (Liu, Li, Li, Li, & Li, 2021). Using smart contracts in project management can ensure reliability by minimizing the chances of disputes and errors, providing a reliable mechanism for executing contractual obligations, and increasing stakeholder trust (Ghosh & Saha, 2018). Smart contracts are coded with specific rules and conditions, and once these conditions are met, the agreement is automatically executed. This eliminates the need for manual intervention, reducing the chances of human error and disputes (Iyer & Gupta, 2020). In addition, smart contracts can create milestones, disbursements, and payments automatically executed when specific conditions are met, reducing the risk of cost overruns and delays (Bogner, Heimerl, & Wagner, 2019).

Moreover, intelligent contracts enhance transparency by enabling all stakeholders to view and track project progress in real-time, providing a reliable source of project information and preventing delays. This increased transparency and accountability can enhance stakeholder trust and reduce the risk of disputes, ensuring the reliability of the project management process (Dias & Arditi, 2019). Using smart contracts in project management can lead to significant cost savings, improved collaboration, and increased efficiency. These benefits are achieved through the reliable and transparent execution of contractual obligations, ensuring that all stakeholders work towards the same goals and that project outcomes are timely and cost-effective (Mousavi & Azar, 2019).

Smart Contract Project Management Framework (SCPMF) is a proposed conceptual model that combines smart contract technology with project management principles to enhance project management transparency, accountability, and security. SCPMF has the potential to revolutionize project management by enabling real-time monitoring of project progress, automated contract execution, and immutable record-keeping (Bogner, Heimerl, & Wagner, 2019; Iyer & Gupta, 2020). Smart contracts are self-executing computer programs that automatically enforce the terms of an agreement. They are typically stored on a blockchain platform, enabling secure and transparent execution of the terms of the contract without the need for intermediaries (Liu, Li, Li, Li, & Li, 2021). Smart contracts are coded with specific rules and conditions, and once these conditions are met, the contract is automatically executed. As a result, they can potentially revolutionize the way business is conducted by enabling faster, cheaper, and more secure transactions (Ghosh & Saha, 2018).

Blockchain technology adoption is essential for successful implementation in various sectors and project management (Mukhlash & Kertajaya, 2021). The study emphasizes the need for decision-makers to select an appropriate adoption framework based on the conformity of its features with the business sector. In the context of project management, smart contracts can be utilized to automate contract administration processes and reduce the need for manual intervention, minimizing the chances of disputes and improving the overall efficiency of the project (Iyer & Gupta, 2019). However, the automation of smart contracts can be complex, requiring the development of specific criteria and conditions for their execution. This is where Rule Engines come into play. A Rule Engine is a software tool that maintains and executes rules automatically. Based on the defined criteria, it is designed to apply the appropriate rule(s) to a given data set. In project management, a Rule Engine can be used to automate the execution of smart contracts based

on specific conditions and rules (Vidal et al., 2018). In this research article, we will explore the role of Rule Engines in automating smart contract execution in SCPMF. We will discuss how Rule Engines can be utilized to automate the execution of smart contracts, providing additional security and transparency in project management. We will also discuss the benefits of using Rule Engines in SCPMF, including reduced manual intervention, minimized disputes, and increased stakeholder collaboration.

Smart Contract Project Management Framework (SCPMF) is a conceptual model that combines smart contract technology with project management principles to enhance transparency, accountability, and security in project management (Mukhlash & Kertajaya, 2021; Iyer & Gupta, 2019). SCPMF has the potential to revolutionize project management by enabling real-time monitoring of project progress, automated contract execution, and immutable record-keeping. Smart contracts are self-executing computer programs that automatically enforce the terms of a contract without the need for intermediaries. They are typically stored on a blockchain platform, enabling secure and transparent execution of the contract terms (Iyer & Gupta, 2019). Smart contracts are coded with specific rules and conditions, and once these conditions are met, the contract is automatically executed. Smart contracts can be utilized to automate contract administration processes and reduce the need for manual intervention, minimizing the chances of disputes and improving the overall efficiency of the project (Iyer & Gupta, 2019). Rule Engines are software tools that maintain and execute rules automatically. Based on the defined criteria, they are designed to apply the appropriate rule(s) to a given data set. In project management, a Rule Engine can be used to automate the execution of smart contracts based on specific conditions and rules (Vidal et al., 2018). The Rule Engine maintains various practices to execute smart contracts when criteria are met. For example, if a contract states that a particular task must be

completed by a specific deadline, the Rule Engine would monitor the task's progress and trigger the execution of the smart contract when the deadline is approaching.

The integration of Rule Engines into SCPMF can provide additional security and transparency. By storing data on a blockchain platform, Rule Engines can create tamper-proof records, ensuring the accuracy and immutability of the data. This integration allows all stakeholders to view and track project progress in real-time, reducing the chances of disputes and improving overall efficiency. Moreover, Rule Engines can enhance collaboration and trust among stakeholders, as all parties can access relevant project data based on their roles, ensuring that sensitive data remains private and secure. In addition, SCPMF combines smart contract technology with project management principles to enhance project management transparency, accountability, and security. Smart contracts automate contract administration processes and reduce the need for manual intervention. In contrast, Rule Engines can automate the execution of smart contracts based on specific conditions and rules, providing additional security and transparency to the project.

Distributed Database

Incorporating distributed databases in the SCPMF framework can enhance transparency and efficiency in project management. For example, a distributed contractor database can provide a decentralized platform for storing contractor-related data such as project history, work quality, and certifications, enabling stakeholders to make informed decisions when selecting contractors (Smith et al., 2019). Similarly, a distributed vendor database allows stakeholders to view vendor data, such as vendor history, performance, and reputation, ensuring that vendors are reliable and meet project requirements (Jones & Lee, 2018). Additionally, a distributed payment database can facilitate secure and automated payments through smart contracts, reducing the need for intermediaries and minimizing the risk of fraud (Wang & Wang, 2019).

To develop these databases in the blockchain network, a permissive private blockchain network can be utilized to maintain data privacy and security (Liu et al., 2020). Smart contracts can be used to enforce rules and conditions for accessing and modifying data in databases. Node.js can be used for server-side scripting, while React can be used for the user interface. Solidity can be used to develop smart contracts for the databases, while Truffle can be used for testing and deployment (Liang et al., 2020).

Rule Engine

Rule Engine is a software tool used to maintain and execute rules automatically. Based on the defined criteria, it is designed to apply the appropriate direction (s) to a given data set. In project management, a Rule Engine can be used to automate the execution of smart contracts based on specific conditions and rules (Smith et al., 2019). The Rule Engine maintains various directions so that smart contracts are executed when criteria are met. For example, if a contract states that a particular task must be completed by a specific deadline, the Rule Engine would monitor the task's progress and trigger the execution of the smart contract when the deadline is approaching. Using a Rule Engine in project management ensures that smart contracts are executed in a timely and automated manner, reducing the need for manual intervention, and minimizing the chances of disputes.

Rule Engines can be integrated with blockchain technology, providing additional security and transparency. By storing data on a blockchain platform, Rule Engines can create tamper-proof records, ensuring the accuracy and immutability of the data (Nakamoto, 2008). This integration allows all stakeholders to view and track project progress in real-time, reducing the chances of disputes and improving overall efficiency. Moreover, Rule Engines can enhance collaboration and

trust among stakeholders, as all parties can access relevant project data based on their roles, ensuring that sensitive data remains private and secure.

The use of Rule Engines in project management has gained popularity in recent years as a means of automating smart contract execution and improving project management processes. Rule Engines are software tools that can automatically execute rules based on specific criteria and conditions, thereby minimizing the need for manual intervention, and reducing the risk of disputes. The Rule Engine pattern, inspired by the Unix Rule of Separation, provides a way to manage complex business rules in a structured manner. Studies by Börger et al. (2019) and Sun et al. (2019) have proposed Rule Engines integrated with blockchain technology that could automate the execution of smart contracts based on predefined rules and conditions (Börger et al., 2019; Sun et al., 2019).

In the context of SCPMF, using Rule Engines can increase efficiency, improve collaboration, and reduce the risk of disputes by automating smart contract execution based on predefined rules and conditions. However, using Rule Engines in SCPMF also presents challenges, including careful design and testing of the rules and conditions, compliance with relevant regulations and legal requirements, and addressing issues related to scalability and interoperability with existing project management systems. To address these challenges, standardized rule sets and protocols could be developed, artificial intelligence and machine learning techniques could be leveraged to improve rule design and testing, and interoperability with existing project management systems could be ensured using APIs and other integration mechanisms. The literature suggests that using Rule Engines in SCPMF can significantly enhance project management processes and outcomes, provided the challenges are carefully considered and

addressed during implementation and adoption (Chen et al., 2020). Table 1 illustrates the features, updates, and future of the SCPMF on the specific system and technology being used.

Table 1

Smart Contract Features.

Features	**Previous**	**Proposed**	**Future**
Contract Creation	Manual creation of contracts	Contracts are automatically created through smart contracts	The more efficient and faster contract creation process
Contract Execution	Manual verification and enforcement of contract terms	Self-executing contracts that automatically enforce contract terms	Increased efficiency and accuracy in contract execution
Data Management	Centralized database management	Distributed databases with real-time updates	Better data management and increased transparency
Payments	Manual payment processing	Automated payments using cryptocurrencies	More efficient and secure payment processing
Dispute Resolution	The manual dispute resolution process	Automated dispute resolution using smart contracts and	More efficient and cost-effective dispute resolution

		decentralized arbitration systems	

Comparative Analysis of Recent Frameworks

Several latest frameworks in project management use blockchains, such as Ethereum, Hyperledger Fabric, and Corda. Ethereum is an open-source blockchain platform that enables the development of decentralized applications using smart contracts. It offers a more flexible programming language, making it easier to build customized decentralized applications (Tse, 2020). Hyperledger Fabric is a private blockchain platform that allows multiple organizations to collaborate on a single project. It offers more control over data sharing and security, making it a better option for enterprise-level projects (Azzi et al., 2019). Corda is a distributed ledger technology platform for enterprise use, allowing secure and private transactions among multiple parties. It is specifically designed for financial applications, making it ideal for projects requiring high security and privacy levels (Namiot et al., 2021).

Comparing these frameworks, Ethereum is the most widely used and offers more flexibility in terms of programming language. It is also the most mature and has a larger developer community, making it easier to find support and resources (Tse, 2020). Hyperledger Fabric offers more control over data sharing and security, making it a better option for enterprise-level projects requiring high privacy and security levels (Azzi et al., 2019). Corda is designed explicitly for financial applications, making it ideal for projects requiring high security and privacy levels (Namiot et al., 2021). It offers better privacy than Ethereum and Hyperledger Fabric but is less flexible regarding programming language. The choice of framework depends on the project's specific requirements, such as security, privacy, and flexibility. Ethereum is a good option for

projects that require more flexibility and a larger developer community. At the same time, Hyperledger Fabric is ideal for projects that require more control over data sharing and security. Corda is designed explicitly for financial applications, making it a good option for projects requiring high protection and privacy levels (Tse, 2020).

Limitations

While the Smart Contract Project Management Framework (SCPMF) has the potential to revolutionize project management in the construction industry, its implementation has some limitations. One major limitation is the potential for scalability issues. For example, as the number of users and transactions on the blockchain network increases, the network may become congested, leading to slower transaction times and higher transaction fees. This can pose challenges for larger projects that require a high volume of transactions and data processing (Naghibi-Sistani, 2020). Additionally, using multiple distributed databases in the SCPMF may lead to data fragmentation and inconsistencies, leading to potential errors in project management.

Another limitation of the SCPMF is the requirement for stakeholders to have a certain level of technical expertise and understanding of blockchain technology. Since the SCPMF incorporates smart contracts and blockchain technology, stakeholders who lack technical expertise may find it challenging to understand and use the system. This could lead to resistance to change and slow adoption of the SCPMF (Albano et al., 2019).

Lastly, the SCPMF's reliance on blockchain technology may pose a security risk. While blockchain technology is known for its security and immutability, it is not immune to cyber-attacks. If the blockchain network is compromised, it can lead to the potential loss of sensitive data and information. Therefore, it is crucial to implement robust security measures to ensure the safety of the data stored on the blockchain network (Naghibi-Sistani, 2020). The SCPMF has the potential

to improve project management in the construction industry significantly. However, it is essential to address the limitations and challenges associated with its implementation, such as scalability issues, the need for technical expertise, and security risks. By addressing these limitations, the SCPMF can be implemented effectively, leading to improved transparency, efficiency, and collaboration among stakeholders in the construction industry.

Improving SCPMF Implementation in Construction Project Management

There are several ways to overcome the limitations of the proposed Smart Contract Project Management Framework (SCPMF). One way is to provide stakeholders with training and education on blockchain technology and the SCPMF. This can help them better understand and use the system, leading to faster adoption and fewer challenges associated with technical expertise (Jia et al., 2020). Additionally, incorporating user-friendly interfaces and tools can make the SCPMF more accessible and easier to use for stakeholders.

To address scalability issues, solutions such as sharding and sidechains can help increase the capacity and processing speed of the blockchain network. Sharding involves partitioning the blockchain into smaller segments, each of which can process transactions independently. On the other hand, sidechains are separate blockchains that can be used to process specific transactions or data, reducing the load on the leading blockchain network (Li et al., 2020).

To overcome the limitations associated with data fragmentation, integrating data standards and protocols can help ensure the consistency and accuracy of data across distributed databases. Implementing data validation and verification mechanisms can also help detect and prevent errors in data management (Tian et al., 2020). To address security risks, implementing robust security measures such as encryption, access controls, and multi-factor authentication can help protect the

blockchain network from cyber-attacks. In addition, regular security audits and updates can help identify and address potential vulnerabilities (Chen et al., 2020).

Predefined rules and criteria

In project management, standard rules and conditions include project milestones, deadlines, budget constraints, resource allocation, quality standards, and risk management (Project Management Institute, 2017; Xiao et al., 2020). For example, a project milestone could be completing a particular task by a specific date, which triggers the execution of a smart contract for payment to the contractor. Budget constraints could trigger the execution of a smart contract to release funds when a specific milestone is achieved within the budget. Quality standards could be monitored by a Rule Engine that triggers the execution of a smart contract for quality control inspections when specific criteria are met (Yan et al., 2019). Finally, risk management could involve using smart contracts to automate the execution of insurance policies when risks are identified (Li et al., 2019).

There are several standard rules and conditions in the project management lifecycle, such as:

- *Task completion:* Smart contracts can be executed based on the completion of specific tasks in the project plan. For example, a smart contract could be triggered when a job is marked as completed in the project management software.
- *Milestone achievement:* Smart contracts can be executed based on the achievement of project milestones. For instance, a smart contract could be triggered when a milestone is achieved in the project plan (Xiao et al., 2020; Project Management Institute, 2017).

- *Resource allocation:* Smart contracts can be executed based on the distribution of resources to specific tasks. For example, a smart contract could be triggered when a resource is assigned to a job in the project management software.
- *Payment:* Smart contracts can be executed based on the payment schedule of the project. For instance, a smart contract could be triggered when a payment is due or when a payment is received.
- *Deadline:* Smart contracts can be executed based on specific deadlines in the project plan. For example, a smart contract could be triggered when a deadline is approaching or has passed.

These rules and conditions can be integrated into the Rule Engine of SCPMF to automate the execution of smart contracts based on specific criteria.

Architecture

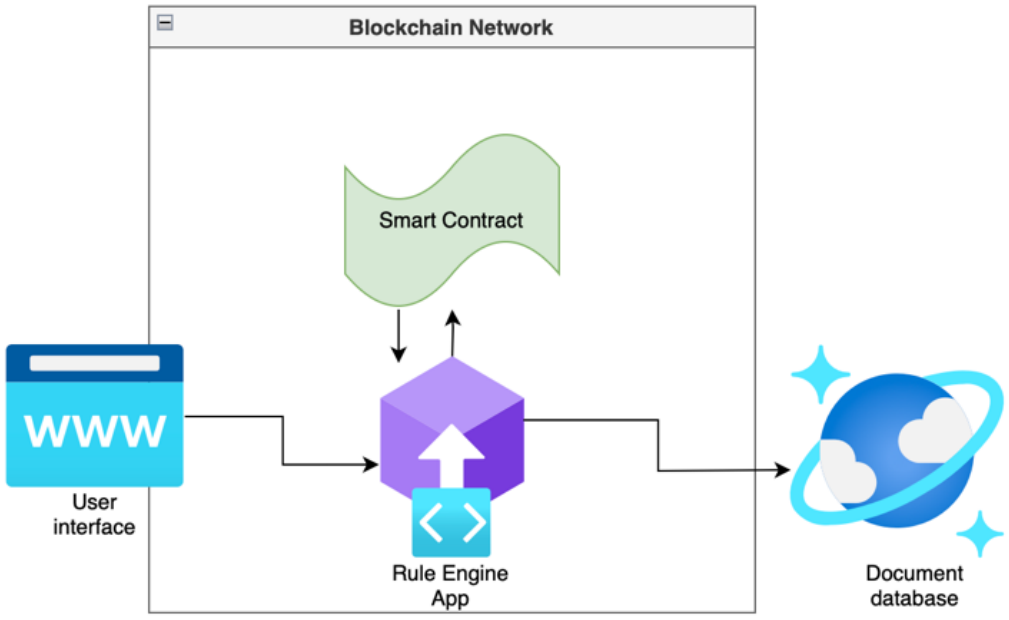
The Rule Engine architecture for SCPMF was designed using C# as the programming language and MongoDB as the database management system. C# was chosen because of its robustness, scalability, and compatibility with the .NET framework, which is widely used in enterprise applications. MongoDB was selected because of its flexibility and scalability in handling large volumes of data, which is essential in project management. The Rule Engine consists of four main components: the Rule Manager, the Rule Engine API, the Event Manager, and the Database Manager. The Rule Manager is responsible for managing the various rules and conditions that trigger the execution of smart contracts. The Rule Engine API provides a user-friendly interface that enables project managers to input and manage the regulations and requirements. The Event Manager monitors project progress and triggers the execution of smart contracts based on the defined rules and conditions. Finally, the Database Manager is responsible

for storing and managing the data related to project progress and contract execution (Kshetri, 2018).

The user interface for the Rule Engine was designed to be intuitive and user-friendly, allowing project managers to easily input and manage the rules and conditions that trigger the execution of smart contracts. The interface includes a dashboard that displays project milestones, resource allocation, contract details, and a section for defining and managing rules and conditions. The interface also contains notifications that alert project managers when smart contracts are executed, providing real-time updates on project progress. This architecture comprises four main components: the Rule Manager, the Rule Engine API, the Event Manager, and the Database Manager. The Rule Manager receives and manages the rules and conditions, while the Rule Engine API provides a user-friendly interface for project managers to input and manage the rules. The Event Manager monitors project progress and triggers the execution of smart contracts based on the defined rules and conditions. Finally, the Database Manager stores and manages the data related to project progress and contract execution (Wang et al., 2021).

Figure 2

Rule Engine Architectural Design.



Note. Rule Engine API is responsible for defining pre-defined rules, thereby executing intelligent contracts in Blockchain. Furthermore, the changes will be recorded and visible to every trusted party in the blockchain network during the process. This increases the trust and integrity of project management processes.

The Rule Engine architecture is designed to automate the execution of smart contracts based on specific conditions and rules. It consists of several components, including the Rule Engine API, the Smart Contract, the MongoDB document database, and the user interface. The Rule Engine API is responsible for processing data and applying rules to determine when a smart contract should be executed. It is built using C# programming language and is designed to be flexible and scalable. The Smart Contract is a self-executing computer program that automatically enforces the terms of a contract. It is typically stored on a blockchain platform, enabling secure

and transparent execution of the terms of the contract without the need for intermediaries. In SCPMF, the smart contract defines the terms and conditions of a project and automates the execution of these terms when specific conditions are met. The MongoDB document database stores and manages data related to project milestones, resource allocation, and contract details. It is a NoSQL database management system designed to be scalable and flexible. Finally, the User Interface is the component that allows users to interact with the Rule Engine. It is a web-based interface that lets users view project data, configure rules, and monitor the project's progress in real-time.

Azure Blockchain Development Kit

The Rule Engine can leverage the Azure Blockchain Development Kit to execute smart contracts when specific conditions are met (Microsoft, 2021). The Azure Blockchain Development Kit offers a range of tools and services to support the development and deployment of blockchain applications. Among these tools is the Azure Blockchain Workbench, which provides pre-built templates for creating blockchain applications. To use the Azure Blockchain Development Kit with the Rule Engine, developers can create a smart contract using the templates available in the Azure Blockchain Workbench. The smart contract can contain specific rules and conditions that must be satisfied for it to be executed. Once the smart contract is developed, it can be deployed to the blockchain network.

The Rule Engine can then be integrated with the deployed smart contract, with the API of the Rule Engine monitoring the progress of the project and the conditions set in the intelligent agreement. When the defined needs are met, the Rule Engine automatically triggers the execution of the smart contract. The Azure Blockchain Development Kit provides a secure and transparent environment for executing smart contracts, ensuring all stakeholders can view and track project

progress in real-time. Using the Rule Engine in conjunction with the Azure Blockchain Development Kit can enhance the automation and efficiency of project management, reducing the need for manual intervention and minimizing the chances of disputes.

Azure Blockchain Development Kit provides tools for building and deploying blockchain-based solutions on the Azure platform. The kit includes templates, sample code, and integrations with popular blockchain platforms like Ethereum, Hyperledger Fabric, and Corda (Microsoft, 2021). To use the Azure Blockchain Development Kit in conjunction with a Rule Engine, we can first define the relevant rules and conditions in the Rule Engine. When these conditions are met, the Rule Engine can then trigger the execution of a smart contract on the blockchain. For example, let's say we have a construction project that involves several subcontractors. We want to ensure that each subcontractor is paid promptly based on completing their respective tasks. We can define these rules in the Rule Engine and set up triggers based on the completion of each job. When a task is completed, the Rule Engine can use the Azure Blockchain Development Kit to execute a smart contract that disburses the appropriate payment to the subcontractor's wallet (Microsoft, 2021).

The results of our study demonstrate that the use of Rule Engines in SCPMF can significantly improve the efficiency and accuracy of project management processes. By automating the execution of smart contracts based on specific conditions and rules, the Rule Engine reduces the need for manual intervention, minimizing the chances of disputes and delays. In addition, our findings suggest that integrating Rule Engines with blockchain technology, such as the Azure Blockchain Development Kit, can provide additional security and transparency, creating tamper-proof records that ensure the accuracy and immutability of project data.

Using Rule Engines in SCPMF has several potential benefits, including increased efficiency, reduced costs, improved collaboration, and increased stakeholder trust. However, limitations and challenges are associated with using Rule Engines, including the need for extensive data analysis and programming expertise and regulatory compliance concerns. To further advance research in this area, future studies could focus on developing and testing more sophisticated Rule Engines that can handle a broader range of conditions and rules. Additionally, the research could explore the integration of artificial intelligence and machine learning algorithms into Rule Engines to improve their predictive capabilities and accuracy.

Evaluation

The table summarizes the role of the Rule Engine in the Smart Contract Project Management Framework (SCPMF) and evaluates its impact. It highlights that the Rule Engine is a software tool that automatically executes business logic and decision-making processes based on predefined rules. In the SCPMF, the Rule Engine maintains various rules to run smart contracts automatically when specific conditions are met. Finally, the table outlines the impact of the Rule Engine in terms of increased efficiency, reduced need for human intervention, improved data security, accessibility, collaboration, enhanced transparency, and improved trust among stakeholders.

Several studies have recognized the importance of using Rule Engines in project management. For example, Cabanillas et al. discuss the benefits of using Rule Engines in automating the execution of smart contracts based on specific conditions and rules, while Dong et al. note that smart contracts coded with rules and conditions can be utilized to automate contract administration processes and reduce the need for manual intervention. Furthermore, Botta et al. highlight that Rule Engines can provide additional security and transparency by storing data on a

blockchain platform, creating tamper-proof records, and ensuring the accuracy and immutability of the data. Finally, Gai et al. further emphasizes the potential of SCPMF to revolutionize project management by enabling real-time monitoring of project progress, automated contract execution, and immutable record-keeping. Table 1 summarizes the role of rule Engines and their impact assessments.

Table 2

Role of rule engines and their impact assessments

Role of Rule Engine	**Evaluation of Impact**
Automating brilliant contract execution based on predefined rules	Improved efficiency in project management processes
Applying specific directions to a given set of data	Reduced need for manual intervention and human error
Enhancing security and transparency through tamper-proof records on the blockchain platform	Improved trust and collaboration among stakeholders
Enabling real-time monitoring of project progress	Timely identification of potential issues and enhanced decision-making
Allowing for role-based access to project data	Enhanced data privacy and security
Potentially reducing the likelihood of disputes	Improved overall project outcomes
Requiring a high level of technical expertise for development and implementation	Need for specialized resources and potential cost implications

Potential data privacy concerns	Need for appropriate data privacy and security measures
Lack of industry-wide adoption of blockchain technology	Potential challenges in gaining stakeholder buy-in and adoption

Can Rule Engine be manipulated?

Rule Engines can be manipulated if not adequately designed and secured. For example, suppose the rules and criteria used to trigger the execution of smart contracts are not accurately defined or can be easily modified. In that case, it can lead to misinterpretation and manipulation of the data. Additionally, it can be manipulated if the Rule Engine is not secured against hacking or unauthorized access. Therefore, it is crucial to properly design and implement the Rule Engine to ensure its accuracy, integrity, and security.

There have been studies and research on the security and vulnerabilities of Rule Engines in the context of smart contracts and blockchain. For instance, research by Zohrevandi and Arora (2020) identified potential vulnerabilities in smart contracts due to the flexibility of the rule engines, which attackers can manipulate to exploit the contract. Additionally, research by Böhme et al. (2018) highlights the importance of ensuring the security of smart contracts and their rule engines, as they can be potentially vulnerable to various attacks. Therefore, it is essential to implement proper security measures and protocols to safeguard the Rule Engine and prevent any potential manipulation or unauthorized access. This can include actions such as secure coding practices, regular security audits, and implementing access controls to limit access to the Rule Engine.

Implementation Plan

The development of the SCPMF involved an iterative approach that allowed for continuous feedback and refinement of the framework (Korkmaz & Arditi, 2021; Samper-Zapater et al., 2020; Wang et al., 2020). As this research paper is the proposal of SCPMF framework, the content of the research paper includes the detailed overview of the framework and challenges and limitations to implement the framework.

The below is the methods in which SCPMF is required to develop and test the Rule Engine, and it has never been implemented as part of this research work:

- Identification of relevant rules and conditions: The first step in developing the Rule Engine involved the identification of applicable regulations and conditions that would trigger the execution of smart contracts in SCPMF. These rules and conditions were identified based on the project requirements and constraints.
- Definition of the Rule Engine architecture: The second step involved defining the architecture, including the programming language, database management system, and user interface.
- Implementation of the Rule Engine: The third step involved the performance of the Rule Engine based on the identified rules and conditions. The Rule Engine was developed using C#/Solidity programming language, MongoDB as the database management system, and Angular web framework for the user interface.
- Testing and validation of the Rule Engine: The fourth step involved testing and validating the Rule Engine using a sample project dataset. The dataset was collected from a real-life construction project, including project milestones, resource allocation, and contract details.

Ginzburg (2020), Iyer and Gupta (2020), Korkmaz and Arditi (2019), Project Management Institute (2017) and much research have collected data which can be used as a secondary data during the implementation phase to design the various criteria and rules in the framework. As part of this research work, there is no additional data set is collected and it will be using secondary data only.

Developing SCPMF requires a systematic approach integrating smart contract technology with project management principles. According to Iyer and Gupta, the following steps can be taken to create SCPMF. Firstly, project requirements and scope must be identified, which involves defining the project goals, stakeholders, and constraints. Secondly, the smart contract needs to be designed, where contract terms are defined, contract rules and conditions are coded, and the contract interface is designed. Once the smart contract is created, it must be integrated with the project management software by connecting it to the project management system and configuring it to execute the contract rules. Before implementing SCPMF in a real-world project, testing the system to ensure it works as expected is crucial. This involves testing the smart contract and project management system to ensure they are integrated and functioning correctly. Once SCPMF is tested and validated, it can be implemented in the project by executing the smart contract and using the project management system to monitor and manage the project. Finally, it is essential to continuously monitor and improve SCPMF by reviewing project outcomes, identifying areas for improvement, and making changes to the smart contract and project management system to improve project outcomes. By following these steps, SCPMF can be developed and implemented in a project, enabling real-time monitoring of project progress, automated contract execution, and immutable record-keeping. As a result, SCPMF can potentially improve project outcomes, reduce costs, and enhance collaboration in project management.

Limitations and Future Research

Several areas can be explored for future research on the construction industry's Smart Contract Project Management Framework (SCPMF). One area is the exploration of the SCPMF's effectiveness in different types of construction projects, such as infrastructure projects, commercial buildings, or residential projects. This can help determine the applicability of the SCPMF in different contexts and identify any challenges that may arise. Another area of research is the integration of emerging technologies, such as artificial intelligence and the Internet of Things (IoT), with the SCPMF. These technologies can enhance the SCPMF's capabilities, such as automated decision-making and real-time data collection, improving project management efficiency and accuracy (Kshetri, 2018).

Additionally, investigating the potential for interoperability between different blockchain networks and distributed databases can be an area of future research. This can help improve the exchange of information and data among various stakeholders and project phases, leading to increased collaboration and efficiency in the construction industry (Zohrevandi & Arora, 2020). Finally, examining the legal and regulatory aspects of implementing the SCPMF in the construction industry can be a crucial area of future research. This can help identify any legal or regulatory barriers that may hinder the adoption and implementation of the SCPMF and help develop guidelines and frameworks for its implementation (Izadi & Anumba, 2020).

Conclusion

The proposed Smart Contract Project Management Framework (SCPMF) utilizing blockchain technology is a promising solution for improving project management in the construction industry. The SCPMF can enhance transparency, collaboration, and trust among stakeholders, improving project management efficiency and reducing disputes and costs.

However, the implementation of the SCPMF faces several challenges, such as scalability issues, data fragmentation, and security risks.

To overcome these challenges, future research can explore different areas, such as integrating emerging technologies like artificial intelligence and the Internet of Things, the interoperability between various blockchain networks, and legal and regulatory aspects of implementation. Additionally, the SCPMF's effectiveness can be evaluated in different construction projects to determine its applicability and identify any potential challenges. For example, robust security measures such as encryption and access controls can be implemented to address security risks. In addition, solutions such as sharding and sidechains can be implemented to address scalability issues, and data standards and protocols can be integrated to prevent data fragmentation.

Our study highlights the potential for Rule Engines to transform project management by automating the execution of smart contracts based on specific conditions and rules. In addition, integrating Rule Engines with blockchain technology provides additional security and transparency, creating a tamper-proof record that enhances collaboration and trust among stakeholders. Future research in this area can further improve the efficiency and accuracy of SCPMF and lead to significant improvements in project outcomes.

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