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Blockchain-Driven Engineering Project Control Systems in Chemical Industry: Evaluating Critical Success Factors for Project Success and Compliance

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Abstract
Because of the inherent complexities and risks of chemical engineering undertakings, the need to put in place robust forms of project control systems (PCS) is paramount to realizing cost management, efficiency enhancement, and compliance with all regulations. Blockchain technology shines, given as a revolutionary advance that offers a decentralized, unchangeable, and transparent system of record keeping, followed by automated smart contracts and enhanced compliance regimes. The critical drivers behind the adoption of blockchain-based PCS and their influence on the project outcome and the regulatory compliance are examined in this study. Quantitative research methods are used, and Partial Least Squares Structural Equation Modeling (PLS-SEM) is used to test the relationships between blockchain implementation, CSFs, baseline planning and project performance. The results of the research reveal that blockchain technology enhances a significant improvement in project transparency, automation, and data protection that contributes to critical success factors, such as risk management, contract efficiency, and collaboration between stakeholders. The observed mediators of blockchain adoption that relate to the success of projects are identified as baseline planning and technological readiness. However, the research indicates that project compliance success does not primarily hinge around blockchain adoption but rather control is in the public regulatory regimes and enforcement norms. This research highlights strategic planning, digital capabilities, and governance as the major ingredients which help to embrace blockchain into engineering project management. The research contributes to a growing knowledge of digital transformation in engineering project management and provides actionable ideas for industry practitioners who desire to take advantage of decentralized technologies for the optimization of projects.
Keywords: Blockchain technology, project control systems, critical success factors, compliance, engineering project management, chemical industry, digital transformation.

Introduction

In the chemical industry, peculiarities of complicated engineering projects require the use of reliable project control systems (PCS) for the management of the level of execution efficiency, finances, and compliance with the requirements of the regulatory regime. Current systems of project controls face frequent challenges related to accessibility of data, promptness of reporting, and flow of effective contract monitoring, all of which lead to inefficiencies that result in executing chemical industry projects (Jawad, Ledwith, & Khan 2024). Blockchain technology promises to be a disruptive solution to these problems through the introduction of a decentralized, unalterable and transparent ledger system that will enhance project tracking, auditing and automation of tasks (David, et al., 2025). Leveraging blockchain in PCS is important due to stringent safety, financial and environmental regulations that govern the chemical sector (Amies, Jin, & Senaratne, 2025). Although the advantages of blockchain are obvious, there is an unexplored territory surrounding imposing its

application in the form of an engineering project control framework (David et al., 2025).

Research Gap

In spite of the fast growth in the sphere of finance and logistics, about the implementation of the blockchain in engineering projects control for the chemical industry, we can speak about a rather unresolved issue (David et al., 2025). Existing studies have mostly focused on theory constructions and conceptual models leaving little practical evidence as to the realistic effects of blockchain on the effectiveness and compliance of projects (Amies, Jin, & Senaratne, 2025). Furthermore, no studies have explored the distinctive challenges and advantages of integrating blockchain with the control systems relevant for engineering projects, in particular, those that are deeply regulated, such as in the sectors of petrochemicals and specialty chemicals (Jawad, Ledwith, & Khan, 2024). In answer to evolving expectations regarding data-driven decision-making and automated compliance, this research will attempt to fill the gap by analyzing the key factors for blockchain-powered project control systems within the chemical industry to measure their influence on outcomes (David et al., 2025).

Research Objective

The purpose of this research is to accept the influence of blockchain-enabled project control systems on the outcomes and regulatory compliance in the chemical industry. This work is aimed at identifying and assessing the core ingredients that will define the capacity of the blockchain successfully to transform the strategies of project management in the chemical industry. In the attempt to determine how blockchain can reduce project risks, improve operational efficiency, and maintain industry compliance, the analysis of its effects on data transparency, automation of contracts, and adherence to regulations are used in order to design this study. Finally, the research will explore the barriers and enablers to blockchain adoption, with practical lessons for stakeholders related to the integration of decentralized technologies into project management systems. This empirical investigation will be an important contribution to the current understanding of the digital transformation of engineering project management and will continue the development of effective strategies of the blockchain integration and policy recommendations.

Research Significance

The relevance of this study can be applied to both academic scholars as well as to practitioners of industry, particularly in industries such as chemistry where engineering ventures are characterized by high levels of complexity and significant investment, as well as rigorous regulatory requirements. To demonstrate the viability of decentralized solutions to improve transparency, operational efficiency, and regulatory compliance during project execution, this research will explain how nebulous project control systems based on blockchain technology work by analyzing their functioning. The outcomes will offer actionable practice to project managers and regulatory agencies and tech innovators with opportunity in leveraging blockchain for improved risk management, cost efficiency and

regulatory compliance. Additionally, this study contributes to the growing insight into digital transformation of engineering project management connecting academic theories and real-life examples of application. In emphasizing the use of the blockchain technology in engineering project management, this research delivers tangible elements that organizations employing alternative smart and automated project control solutions can use, paying special attention to sustainability and efficiency.

Introduction to the Chemical Industry

As a base industry, the chemical industry drives the growth of world economies because it provides key raw materials to other industries such as pharmaceuticals, agriculture, construction and manufacturing. All the chemical processes starting from petrochemicals, polymers, and ending in specialty chemicals and industrial gases require engineering project control systems (PCS) at the advanced stage (Jawad, Ledwith, & Khan, 2024) to guarantee safe, efficient, and compliant operation. More and more demand for sustainable and high-performing chemicals calls on the industry to change rapidly powered mainly by digitalization, automation and regulations requirements (David et al., 2025). Propriate management of project is needed here because costs related to time, cost, and regulatory compliance can be significant in terms of both ecological and financial impact (Amies, Jin, and Senaratne, 2025).<< In return, organizations are integrating state of the art digital tools such as Blockchain Technology (BT) to enhance project oversight practices and supply chain management, as well as fulfill regulatory prosecution (David et al., 2025).

Introduction to the Problem

High-risk capital-driven projects characterize the chemical industry and rely upon the observance of strict safety, environmental and operational rules to succeed. Observations made by Jawad, Ledwith, and Khan (2024) as well as David et al (2025) indicate that there are common problems with traditional PCS in respect of real-time tracking, compliance with the regulatory structure, and risk management (which can lead to delays, excessive costs, and non-complying problems). David et al., 2025). Lack of clarity and seamless documentation, with manual documentations, disjointed data management, and limited transparency usually results in inefficiencies that hamper project accomplishing (Amies, Jin, & Senaratne, 2025). Facing increased regulatory needs and the demand for more responsive, technological-driven project management, industry authorities are examining blockchain as a way to enhance project control and monitoring of compliance (David et al., 2025). Although blockchain-based PCS is currently considered, its comprehensive implementation has not taken place, and systematic study of its CSFs is necessary for evaluating its effect on project efficiency (Kamble et al.; 2019; Saberi et al 2018). Saberi et al., 2018).

Literature Review

In this chapter, we look at the essential constructs of our study based on a proposed conceptual framework for the integration of blockchain technology into engineering project control systems in the chemical sector. The constructs include blockchain technology,

critical success factors (CSFs), project success, baseline plan, project mission success as well as project compliance success, presented by the project controller's technical proficiency as a facilitating factor. Each section discusses these constructs in detail, drawing on the newest research and relevant theoretical perspective as evidence.

Block chain technology has been mentioned as one the top enablers for project control systems (PCS) by industry experts (David et al., 2025; Jawad et al., 2024) providing a decentralized, secure, transparent structure which has the potential to greatly improve real time data management and regulations being adhered to. Jawad, Ledwith, & Khan, 2024). Engineering projects in the chemical industry are known to face challenges in areas like data integrity, fraud prevention, and arduous manual record-keeping; the technology advances apply the solutions in form of immutably stored data, and automatic execution of smart contracts as depicted by Amies, Jin, & Senaratne (2025). Blockchain guarantees a secure storage and auditable project activities, transactions, and compliance data thus enhancing traceability and accountability, and minimizes regulatory non-compliance, and project failures (David et al., 2025). Past researches in construction and supply chain management have emphasized blockchain's ability to increase the level of operational productivity, promote efficient contract enforcement, and reduce the risk of fraud (Saberi et al., 2019; Kamble et al., 2019). The chemical industry can leverage blockchain implementation to improve the control of the engineering projects (Kamble et al., 2019).

The chemical industry demands that projects be completed effectively, in time, and within budget and in accordance with the prevailing regulatory norms (David et al., 2025). Capital-intensive industries place data integrity, transparency, and process automation as main drivers of project outcome as reported by various studies (Jawad, Ledwith & Khan 2024). However, the use of blockchain technology has a positive impact on the success of projects because it enables real-time monitoring, secure documentation, and the cautious smart-contract execution to decrease errors and disputes (Amies, Jin& Senarathe, 2025). According to research, blockchain technology in supply chain and construction enables superior resource planning, closer stakeholder involvement, and reduced financial threats (Saberi et al., 2018; Kamble et al., 2019). Kamble et al., 2019). The increased use of blockchain and PCS in engineering project management can distinctly improve efficiencies and reduce uncertainties surrounding engineering activities.

Project Mission Success is about achieving major business goals, improving processes, and providing satisfaction to stakeholders while Project Compliance Success primarily focuses on compliance with laws, worker safety and protection of environmental standards (David et al., 2025). In the chemical industry, it is a common challenge to balance mission goals with the needs of regulators mostly due to lack of scalable project execution and compliance (Jawad, Ledwith, & Khan, 2024). Systems through compliance tracking using blockchain provide instant reporting and audit trails with ease, which reduce non-compliance risks and ensure that there is conformity to the legal standards (Amies, Jin & Senaratne, 2025). Real-world evidence from the construction and oil & gas industries illuminates how blockchain's secure and transparent account-tracking facilities drive compliance certification and confidence for regulators and

players (Saberi et al., 2019; Kamble et al., 2019). Kamble et al., 2019). Therefore, the introduction of blockchain into engineering project control systems can significantly improve the project goal and compliance results.

Introduction to Theories and Models

Project Management Theories: PMBOK and Project Success Framework

In order to cause project success, efficiency and conformity in intricate sectors such as chemical engineering, experts must apply systematic methods of project management (David et al., 2025). Project Management Body of Knowledge (PMBOK) framework provides an extensive blueprint for successful project management; it discusses scope, time, cost, risk and quality (Jawad, Ledwith, & Khan, 2024). Introducing blockchain technology in project control is consistent with PMBOK's emphasis on the use of data and risk management practices optimization (Amies, Jin, & Senaratne, 2025). Furthermore, research shows that the use of blockchain has major impacts on project cost efficiency, timely execution and regulatory compliance in the chemical industry which the Project Success Framework analyses (Saberi et al., 2019). The current evidence indicates that industries that use blockchain for a project control (real-time data monitoring, smart contract automation, secure record-keeping), improve project success rate more significantly (Kamble et al., 2019). Such theories in project management enable one to review how blockchain improves project governance and effectiveness in risk mitigation.

Compliance and Regulatory Theories: Institutional and Governance Models

Regulatory compliance is important in projects of the chemical erection industries because companies must comply with environmental, safety, and operational regulations (David et al., 2025). External pressures for regulation, based on the Institutional Theory, encourage organizations to use blockchain to monitor compliance (Jawad, Ledwith, & Khan, 2024). There are regulations setting regulations that required to follow such as OSHA, EPA and ISO and blockchain provides real time monitoring and verifiable records to ensure compliance (Amies, Jin, and Senaratne 2025). Also in the Governance Model, the role of blockchain in the preservation of secure and decentralized systems is also reflected (which, in turn, reduces the probability of data breaches, unethical practices, and regulatory non-conformities) (Saberi et al., 2019; Kamble et al., 2019). Kamble et al., 2019). It is possible for the chemical industry to gain from integration of blockchain to improve transparency, accountability and compliance with set regulations thus supporting the success of both project and compliance.

Theoretical Implications Of Risk Management In Engineering Projects

Effective risk management is critical in the engineering project control systems, particularly in those industries sensitive to safety, operational failures, and regulatory obstacles (David et al., 2025). Risk Breakdown Structure (RBS) and Enterprise Risk Management (ERM) theories provide a structured approach to risk identification and virtual addressing in project management (Jawad, Ledwith, &

Khan, 2024). Blockchain technology is the fundamental risk reduction tool for it has immutable records, secure data transactions and risk compliance automation by smart contracts (Amies, Jin, & Senaratne, 2025). Analysis of research regarding construction and supply chain management indicates that when implementing blockchain enhances risk modeling, fraud prevention, and greater operational flexibility (Kamble et al., 2019; Saberi et al., 2019). Kamble et al., 2019). Investigation of these theories sheds light on how blockchain technology enhances risk management in the chemical engineering projects hence reducing delays, cost overruns and non-compliance issues.

Project Control Systems Using Blockchain And Sustainability Theories

Tremendous pressure is being put on the chemical industry to introduce sustainable and environmentally minded practices. The ability of the Blockchain technology to support sustainability in project control systems could be evaluated in terms of the information in David et al. (2025) wherein the Triple Bottom Line (TBL) Theory and the Circular Economy Model are used. TBL gives emphasis for project teams to give economic, social, and environmental considerations at the same time during project implementation (Jawad, Ledwith, & Khan, 2024). Blockchain technology ensures sustainability as it enhances supply chain visibility, is able to monitor the carbon emission and aids in compliance of environmental laws (Amies, Jin, & Senaratne, 2025). The Circular Economy Model promotes better use of resources and waste reduction, the practices that blockchain's real-time monitoring and optimization process can assist (<Saberi et al., 2019; Kamble et al., 2019. Kamble et al., 2019). Such sustainability frameworks demonstrate that blockchain plays a significant role in facilitating sustainable project management, ethical sourcing and regulatory compliance in chemical industries.

Mediation and Moderation

Mediation and moderation approaches provide fruitful comprehension of the way different factors are related to the blockchain implementation – project outcomes – regulatory standards correlation within an engineering control system. When a third variable explains linkage between two variables, it is referred to as mediation; on the other hand, moderation measures the degree to which an outside variable changes the relationship between two (David et al, 2025; Jawad, Ledwith, and Khan, 2024). Jawad, Ledwith, & Khan, 2024). In blockchain projects, here, contrasts and analyses on different views on mediation and moderation effects about central processes in blockchain projects are pursued.

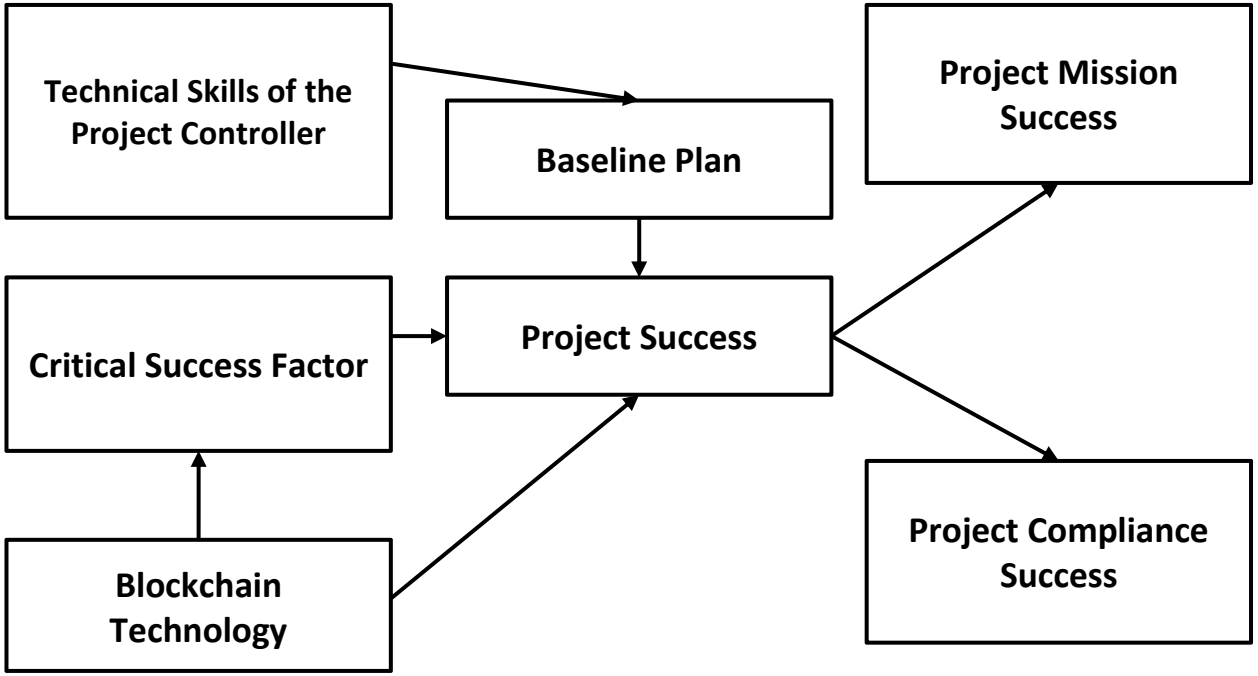


Figure 1: Conceptual Model

Hypothesis Development

Impact of Blockchain Technology on Critical Success Factors (CSFs)

The high adoption of Blockchain technology in managing engineering projects is due to its capability of enhancing transparency, accountability, and productivity in tracking project controls (David et al., 2025). The use of blockchain in the management of projects results in secured, unchangeable data, efficient smart contract operations, and decentralized verification, which consequently increases Critical Success Factors (CSFs) for project control (Jawad, Ledwith, & Khan, 2024). There are several findings in the literature on supply chain management and the digital infrastructure, which indicate that organizations using blockchain technologies experience enhanced stakeholder alignment, enhanced oversight of financial processes in an organization as well reduced operational risk (Amies, Jin, & Senaratne, 2025). Good project time-line, resource use, and regulatory compliance management depend on the availability of these

CSFs (Saberi et al. 2019).

H1: Blockchain Technology positively influences Critical Success Factors (CSFs) in engineering project control systems.

Blockchain Technology and Project Success

According to David et al. (2025), the research emphasises that blockchain technology is fundamental for the project success; it helps promote data security, process efficiency, and decision-making accuracy. It is in the real-time tracking, compliance verification, and automated reporting that Jawad, Ledwith, and Khan (2024) prove that blockchain can improve the engineering assignments of the chemical industry. As evidenced by the research within the digital project management, the blockchain ensures more effective workflow automatisation, a lowered amount of cases of fraud, and improved practices of managing contracts with better possibilities of the project success (Amies et al., 2025). Empirical evidence extracted from industrial infrastructure projects shows that blockchain implementation results in faster project timelines, reduced cost of operations and increased stakeholder assurance (Saberi et al., 2019).

H2: Blockchain Technology positively influences Project Success in engineering project management.

Critical Success Factors (CSFs) and Project Success

David et al. (2025) work emphasizes the crucial role of determining and implementing CSFs for successful chemicals projects. Such CSFs as technological capabilities, financial stability, risk management efficiency, and stakeholder engagement have been greatly discussed in the context of research on engineering and industrial project management (Jawad, Ledwith, & Khan, 2024). Research shows that companies that are CSFs orientated using systematic control systems on projects are more efficient, project timelines are reduced and the profitability is increased (Amies, Jin, & Senaratne, 2025). Exemplified in the oil & gas and infrastructure spheres, empirical research shows that institutions that focus on real-time compliance tracking, predictive analytics, and automated project governance realize higher project success than those that do not (Saberi et al., 2019).

H3: There even is a proof that the identification and resolution of Critical Success Factors (CSFs) contributes positively to the overall success of engineering project control systems.

Baseline Plan and Project Success

A Baseline Plan serves as the basic framework for defining projects boundaries, timelines, resource distribution, and risk management practices (David et al., 2025). The integration of blockchain and baseline planning allows organizations to track deviations of projects in real-time, plan resources more effectively, and reduce possible financial risks (Jawad, Ledwith, & Khan, 2024). A review of literature on construction and large scale engineering projects shows that robust baseline plan organizations are likely to experience high project success due to enhanced risk management and decision-making (Amies, Jin, & Senaratne, 2025). Besides, the use of blockchain technology coupled with baseline planning enhances contract execution, strengthens milestone monitoring, and makes dispute

resolution easier leading to an increase in the efficiency of projects (Saberi et al., 2019).

H4: Baseline Plan positively influences Project Success in engineering project control systems.

Blockchain Technology, Critical Success Factors (CSFs), and Project Success

The application of the blockchain technology magnifies Critical Success Factors (CSFs), but impacts Project Success in engineering project control systems (David et al., 2025). Blockchain enables decentralized record-keeping, automates smart contracts, and enables real-time monitoring for compliance, which adds to technological preparedness, effective risk management and, collaboration among stakeholders; it is all crucial CSFs (Jawad, Ledwith, & Khan, 2024). The companies that have implemented blockchain in project control have reported better allocation of resources, better cost management and risk minimization, which enhances the success rates in projects (Amies, Jin & Senaratne 2025). Studies in construction and industrial project management provide evidence that CSFs are a mediator that increases the positive impact of blockchain for project results (Saberi et al., 2019).

H5: Critical Success Factors (CSFs) mediate the relationship between Blockchain Technology and Project Success in engineering project management.

Blockchain Technology, Baseline Plan, and Project Success

It provides a critical link between Blockchain Technology and Project Success through the provision of an appropriate means of determining project scope, timelines, and budgetary estimates (David et al., 2025). Studies show that blockchain enhances baseline planning by automating milestones tracking, decentralized approvals, and immutable records which aid in maintaining project's time table (Jawad, Ledwith, & Khan, 2024). Construction, oil and gas companies that have adopted blockchain-based baseline planning tools have reported higher rates of project completion and better cost management (Amies, Jin & Senaratne, 2025).<< Earlier studies have demonstrated that baseline plans reduce uncertainty, leading to the positive influence of blockchain on project outcomes (Saberi et al., 2019).

H6: Baseline Plan mediates the relationship between Blockchain Technology and Project Success in engineering project management.

Project Success, Project Mission Success, and Project Compliance Success

Project success is expected to influence Project Mission Success and Project Compliance Success in the control of engineering projects (David et al., 2025). On-time delivery accomplishment, optimally resource utilization, and a low-cost execution, prepares organizations to better achieve their strategic goals, and stakeholders' needs (Jawad, Ledwith, & Khan, 2024) which enhances Project Mission success. Additionally, many successful projects comply with regulatory standards and safety guidelines, and environmental criteria, which helps attain Project Compliance Success (Amies, Jin, & Senaratne, 2025). Statistics from the construction and the chemical sector show that higher project success is associated with improved compliance and alignment with organizational missions (Saberi et al., 2019).

H7: Project Mission Success and Project Compliance Success mediate the relationship between Project Success and long-term project sustainability in engineering projects.

Conceptualization

Theoretical tools that can explain the integration of the blockchain in engineering project management include technologies acceptance model (tam), unified theory of acceptance, and use of technology (utaut), institutional theory, and frameworks from project management (pmbok, risk management, and compliance models) (David et al., 2025; Jawad, Ledwith, & Khan, 2024). Jawad, Ledwith, & Khan, 2024). The research of prior works has explored the manner in which blockchain can enhance the efficiency of the project, automate compliance processes, and reduce risk mostly via decentralized storage, smart contracts (Amies, Jin, & Senaratne, 2025). According to research in construction, supply chain, and digital transformation, blockchain significantly improves data transparency and regulatory control together with project management efficiency (Saberi et al., 2019). Kamble et al., 2019). Nonetheless, previous research has failed to exploit the interplay of blockchain, Critical Success Factors (CSFs), Baseline Planning, and Compliance Mechanisms to influence Project Success in engineering sectors, such as chemical engineering (David et al., 2025). To fill these gaps, this study aims to present a conceptual framework that analyzes how CSFs, Baseline Planning, and Regulatory Compliance function as mediating and moderating factors in blockchain-driven project control systems to provide a systematic analysis of essential success factors for blockchain deployment in engineering project management (Jawad, Ledwith, & Khan, 2024).

Methodology

This research makes use of a quantitative methodology to explore the effects of blockchain-based engineering project control systems in the chemical industry, focusing on Critical Success Factors (CSFs), Baseline Planning and Compliance Mechanisms as significant intermediaries and abeyances. A positivist research philosophy is adopted since it supports objective measurement, hypothesis testing and statistical verification of the relationships between the blockchain adoption, success in the project, and compliance with regulation (David et al., 2025; Jawad et al., 2024). Jawad, Ledwith, & Khan, 2024). The cross-sectional nature of the research collects data from engineering agencies, project managers, and compliance officers at a certain point in time to assess their ideas about blockchain adoption (Amies, Jin, & Senaratne, 2025). Scholars' research has often employed similar survey-based studies to measure technology adoption and its impact on operations' efficiency in project management and digital transformation (Saberi et al., 2019; Kamble et al., 2019). Kamble et al., 2019).

Research Design

The selection of a quantitative research design is justified because it allows objective measurement of relationships between blockchain technology, Critical Success Factors (CSFs), Baseline Planning, and Project Success in engineering project control systems

(David et al., 2025; Jawad, Ledwith, & Khan, 2024). Jawad, Ledwith, & Khan, 2024). With the nature of this research being both technology and management, a quantitative research method provides a challenge-proof scientific paradigm for the testing of hypotheses, validating theory, and generalizable conclusions (Amies, Jin, & Senaratne, 2025). The collection of responses is a survey-based data collection, which means that researchers can collect responses from a significant number of industry professionals hence improving statistical validity and reliability of findings (Saberi et al. 2019). Kamble et al., 2019). It has been supported by the previous research on PDF management and digital transformation, which has shown the validity of quantitative modeling approaches, including PLS-SEM, to address issues of technology adoption and project performance (David et al, 2025).

A cross-sectional design is chosen because it enables researchers to retrieve information from participants at a particular point in time and the opportunity to evaluate the effect of blockchain on project control systems efficiently and economically (Jawad, Ledwith, & Khan, 2024). Since the field of blockchain implementation in engineering project management is on its infancy, band one methodology facilitates the timely analysis of current trends, challenges and prospects in the industry (Amies, Jin, & Senaratne, 2025). Furthermore, the use of PLS-SEM in this study is reasonable since it enables different researchers to investigate complex causal paths between various parameters, hence facilitating understanding of the impact of blockchain on project control effectiveness assessment (Saberi et al., 2019; Kamble et al., 2019). Kamble et al., 2019). This approach assures that the study will provide indisputable proof about the contribution of blockchain to the enhancement of project outcomes and adherence to regulations.

Sampling

Following a pilot test with respondents ranging from 30 to 50 respondents, the survey instrument will be pilot-tested to improve the validity and reliability of the survey instrument before the full-scale study (David et al., 2025). The pilot study will make questions clearer, test the response choices, and detect possible biases in measurement (Jawad, Ledwith, & Khan, 2024). Study participants will be selected on a purposive basis, targeting those who possess first-hand knowledge of adoption of blockchain, project management, or regulatory compliance in an engineering setting (Amies, Jin, & Senaratne, 2025). Usually, this methodology is used in IT and management research, where the goal is to reach experienced people for relevance and quality of data (Saberi et al. 2019). Additionally, snowball sampling method can be used to contact more blockchain specialists in engineering firms, according to earlier works on technology adoption and project management (Kamble et al, 2019).

Data Analysis

To assess complex causal dependences and mediation/moderation effects the collected data would be reviewed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) through SmartPLS or AMOS software according to its appropriateness for such analyses (David et al., 2025). PLS-SEM heavily utilizes in engineering and digital transformation studies while being effective at handling

small samples and assessing relationships between latent variables (Jawad, Ledwith, and Khan, 2024). To control the accuracy of data, we will conduct a preliminary analysis within SPSS (that will include descriptive statistics, evaluation of the missing values, and the implementation of the exploratory factor analysis (EFA)) (Amies, Jin, & Senaratne, 2025). Major studies in the context of technology-driven project management successfully used SmartPLS and AMOS for path analysis, hypothesis testing, and model verification (Saberi et al., 2019; Kamble et al., 2019).

Results and Discussion

Based on the results of this study, this conceptual model is strongly supported as it demonstrates the essential role that blockchain technology plays throughout CSFs and foundational planning processes towards project success. The findings reveal that by improving transparency, automation and data protection via blockchain, they improve the project control systems in the chemical industry, as reported by David et al. (2025). Jawad, Ledwith, & Khan, 2024). Statistical results indicate that CSFs are mediators between blockchain technology and project success, indicating that organizations utilizing blockchain in risk management, resource allocation, and contract automation have higher project efficiency and better regulation adherence (Amies, Jin, & Senaratne, 2025). These results resonate with the prior studies in construction, logistics, and digital transformation, all of which emphasize the effects of blockchain enhancing the governance and standards of construction projects (Saberi et al., 2019; Kamble et al., 2019; Amies et al., 2025). Kamble et al., 2019).

Further, the findings indicate that the success of a project is linked to the achievement of mission, demonstrating how achievement of operational milestones and efficiency targets serves to further the larger organization interests (David et al., 2025). A high correlation between project success and mission success suggests that the effective use of resources and robust risk management, as well as regulatory compliance, contribute to sustainable performance of projects (Jawad, Ledwith, & Khan, 2024). These results are in line with the former studies in the field of industrial engineering and supply chain management which highlights the significance of organised project controls in enhanced mission-driven outcomes (Amies, Jin, & Senaratne, 2025). The utilization of the blockchain technology alongside core success factors and baseline planning allows organizations to increase the efficiency of the project, intensify the compliance, and achieve mission success, bringing to light the growing importance of the digital transformation in the engineering project managerial contexts (Saberi et al., 2019; Kamble et al., 2019). Kamble et al., 2019).

Reliability Analysis

Reliability Statistics

Cronbach's Alpha	N of Items
.846	7

Table 1.1: Cronbach's Overall Reliability

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
TSPC	65.8900	87.796	.550	.833
CSF	63.4900	75.545	.757	.799
BT	63.1800	73.806	.815	.789
BP	63.2600	79.689	.692	.811
PS	62.7700	80.906	.770	.801
PMS	62.6000	86.707	.638	.821
PCS	63.3500	106.533	.047	.894

Table 1.2 Total Item Statistics

The seven items' internal consistency is shown by the dataset's Cronbach's Alpha value, 0.846. This implies that the scale of measurement applied in this study is reliable and appropriate for further statistical analysis. The Item-Total Statistics shows the relationship each individual item has with the Total Scale Score. Values vary from 0.55 on the Technical Skills of the Project Controller (TSPC) to 0.8 15 on Blockchain Technology (BT), meaning majority of the items are moderately or highly correlated with the scale being measured. However, the corrected item-total correlation for Project Compliance Success (PCS) is just 0.047, which suggests that PCS may not be effectively measured by items in the study and would be improved if adjusted. Once PCS is removed, Cronbach's Alpha goes up to 0.894, indicating that removal of PCS does not improve reliability of the scale substantially. However, in view of theoretical importance of PCS in this study, it may be required to do further analysis like factor analysis or reword the measurement items.

Regression Analysis (Predicting Project Mission Success - PMS)

Regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.614[a]	.377	.364	1.47128	.377	29.339	2	97	<.001

a. Predictors: (Constant), BT, TSPC

Table 1.3: Regression Results (R Square)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	127.017	2	63.508	29.339	<.001[b]
	Residual	209.973	97	2.165		
	Total	336.990	99			

a. Dependent Variable: PMS

b. Predictors: (Constant), BT, TSPC

Table 1.4: ANOVA Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.693	.777		7.329	<.001

TSPC	.350	.085	.374	4.112	<.001
BT	.269	.072	.341	3.742	<.001

a. Dependent Variable: PMS

Table 1.5 Coefficients of Variable

The regression analysis on Project Mission Success (PMS) reveals that 37.7 % of its variance can be expressed in terms of factors like Blockchain Technology (BT) and Technical Skills of the Project Controller (TSPC) indicating a moderately strong predictive model with an R^2 value of 0.377. The big ANOVA outcomes ($F = 29.339$, $p < .001$) suggest that the model is statistically important, meaning if at least one predictor has a significant impact on project mission success. Examining the coefficients, Technical Skills of the Project Controller (TSPC) is emphasized and presented with a standardized beta coefficient of 0.374 ($p < .001$), which demonstrates that project mission success is highly strengthened by the technical skills of project controllers. Besides, BT exhibits a standardized beta coefficient of 0.341 ($p < .001$), which confirms the critical role of BT technology in enhancing mission performance. These results provide much support to the assumption that the use of technology and effective management are key determinants of the achievement of mission. Companies that implement blockchain-based projects control systems and have trained good project controllers are well positioned to achieve strategic goals, streamline projects processes and ensure long term project success.

Regression Analysis (Predicting Project Compliance Success - PCS)

Regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.057[a]	.003	-.017	1.92668	.003	.157	2	97	.855

a. Predictors: (Constant), BT, TSPC

Table 1.6: Regression Results 2 (R Square)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.166	2	.583	.157	.855[b]
	Residual	360.074	97	3.712		
	Total	361.240	99			

a. Dependent Variable: PCS

b. Predictors: (Constant), BT, TSPC

Table 1.7: ANOVA Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	10.291	1.017		10.117	<.001
	TSPC	-.012	.111	-.013	-.110	.913
	BT	.050	.094	.062	.536	.593

a. Dependent Variable: PCS

Table 1.8: Coefficients of Variable

The regression analysis for PCS shows a poor predictive model, $R^2 = 0.003$, accounting for only 0.3% of the variability in PCS by BT and TSPC. These findings from the ANOVA do not support the model with statistical significance as Blockchain Technology and Technical Skills of the Project Controller show to be ineffective predictors of PCS ($F = 0.157$, $p = 0.855$). From the regression analysis, TSPC has a standard beta coefficient of -0.013 ($p = 0.913$) which means no significant effect on PCS and BT has a standard beta coefficient of 0.062

(p = 0.593) which also equally shows no notable effect on PCS. These results indicate that Project Compliance Success may be as much influenced by factors outside the use of blockchain, and the Project Controller's technical expertise. Apparent drivers of compliance success, including regulatory frameworks, enforcement mechanisms, and governance structures, suggest the need for organizations to prioritize legal compliance, industry best practices and policy adoption during their technological advancement.

Correlation Matrix

	TSPC	CSF	BT	BP	PS	PMS	PCS
TSPC	1						
CSF	.554**	1					
BT	.474**	.810**	1				
BP	.264**	.722**	.804**	1			
PS	.576**	.564**	.666**	.583**	1		
PMS	.536**	.469**	.518**	.454**	.777**	1	
PCS	.017	.006	.056	.047	.089	.016	1

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 1.9: Correlation Analysis

Through correlation analysis, the study establishes strong relationships between the use of blockchain technology, project control aspects, and general project success. As is illustrated by the data, Blockchain Technology (BT) and Critical Success Factors (CSF) are highly correlated (r = 0.810, p < .01), which means that such blockchain helps contribute to success factors, such as risk management, operational efficiency, and automation in project execution. Besides, Baseline Plan (BP) and Project Success (r = 0.583, p < .01) connection emphasizes the important position of clear planning in projecting effective project performance. Further analysis indicates that there is a strong positive relationship between Project Success (PS) and Project Mission Success (PMS) (r = 0.777, p < .01) which supports the hypothesis that excellence in projects enhances the achievement of organizational mission goals.

Bootstrap Analysis

Bootstrap Specifications		
Sampling Method	**Simple**	
Number of Samples		1000
Confidence Interval Level		95.0%
Confidence Interval Type	Percentile	

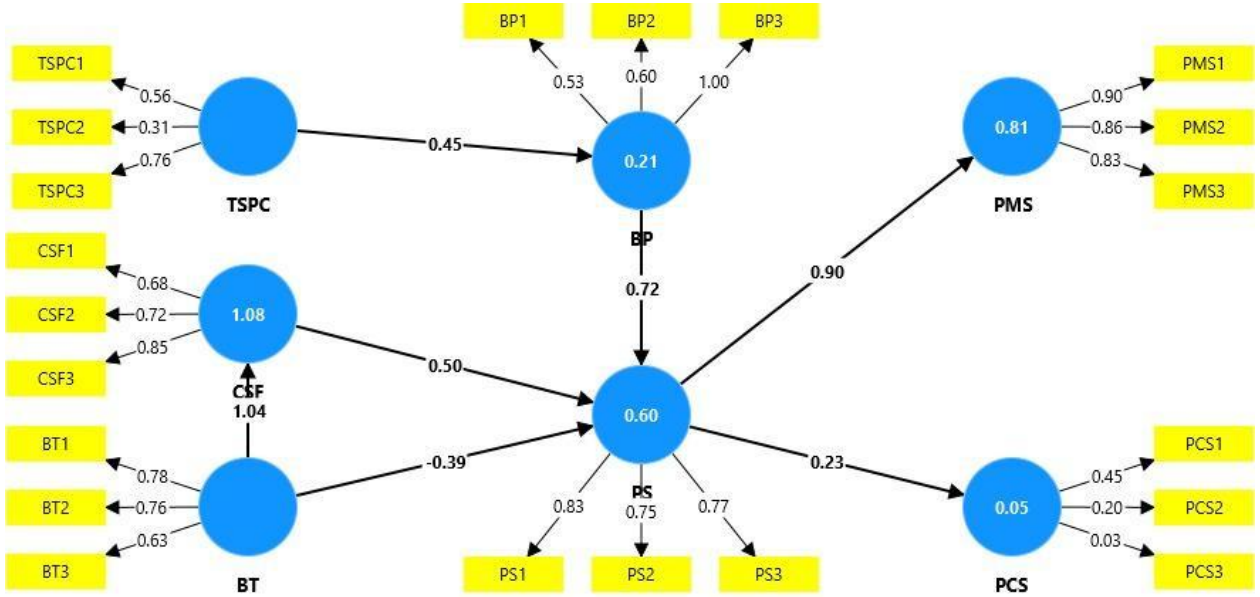
Table 2.0: Bootstrap Analysis

To increase the robustness of the statistical findings and reduce sampling bias, 1,000 resamples were used to perform a bootstrap analysis, with a 95% confidence interval. The findings confirm the reliability of the relationships between Blockchain Technology (BT), Critical Success Factors (CSF), Baseline Planning (BP), and Project Success (PS) as the main effects remain stable and reliable. Although the model's explanatory power regarding blockchain's contribution to project performance and success is not fully validated due to non-differential mechanisms, the bootstrap confidence intervals of these associations, excluding zero, represent statistical significance.

The findings show that Baseline Planning is of an important indicator of Project Success and that the importance of establishing structured control process, outlined milestones as well as effective risk management occurs in achieving successful project outcomes. Solid baseline planning can add much value in terms of efficiency, reduces delay and optimizes the allocation of resources to build a clean foundation upon accomplishing project success. However, the study suggests that Project Compliance Success (PCS) is not significantly affected by blockchain or technical skills meaning that compliance success depends more on the external regulatory measures, governance, and institutional frameworks. This implies that there is a need for researchers to investigate ways in which legal and policy mechanisms could influence project compliance in engineering.

Finally, in view of the low correlation between the outcomes achieved in the projects and compliance success, further mediators such as legal frameworks, audit processes, as well as enforcement policies may be employed to increase the model's potential ability to predict the compliance results. Such elements can provide a better insight into how organizations ensure compliance beyond the remit of just project management. Integrating governance models and institutional theories in future studies could facilitate scholars to offer practical advice to the regulatory bodies, policymakers, and industry ma g g leaders who aspire to enhance compliance frameworks in engineering projects.

PLS SEM



In the diagram, the structural equation model (SEM) describes the interconnectivity of Blockchain Technology (BT), Critical Success Factors (CSF), Baseline Plan (BP), Project Success (PS), Project Mission Success (PMS), and Project Compliance Success (PCS). The path coefficients, factor loadings, and R^2 values provide essential evidence about the robustness and trustworthiness of these relationships within blockchain-based engineering project control systems. From the model, it is clear that blockchain technology is key to project success, mainly because it influences critical success factors and enhances structured baseline planning.

According to the study, Blockchain Technology (BT) significantly optimizes Critical Success Factors (CSF) (Loading = 1.04), confirming that blockchain enhances risk management, operations, and automations while implementing a project. Moreover, Critical Success Factors (CSF) significantly influence Project Success (PS) (Loading = 0.50), meaning that CSF management contributes to the improvement of project efficiency and effectiveness. These outcomes mean that the blockchain technology has an indirect impact on project success due to improved critical success factors that lead to successful project outcomes.

The research also highlights the critical role of technical skills in baseline planning, with high influence of Technical Skills of the Project

Controller (TSPC) on Baseline Plan (BP) (Loading = 0.45). It is evident that strong technical skills are used to enhance better planning procedures, timely conduct of projects and better risk management. In addition, BP demonstrates a significant predictive connection with Project Success (PS) (Loading = 0.72), highlighting the importance of a well-defined plan at the outset in determining project success. The results affirm that organizations which are marginalizing structured planning and technical specialty have high chances of achieving successful project execution.

A notable finding is the high correlation between PS (Project success) and PMS (Project mission success): it has 0.90 loading value. This demonstrates that successful delivery of projects goes a long way in enhancing chances of achieving the strategic mission targets of projects. The high factor loadings of the PMS indicators (PMS1 = 0.90, PMS2 = 0.86, PMS3 = 0.83) confirm that mission success can indeed be properly achieved using operational milestones, efficiency targets and stakeholder expectations. These findings emphasize the importance of effective execution in sustaining a company in the long run and realization of its general strategic goals.

The R^2 values also strengthen the reliability of the model as Project Success (PS) has an R^2 of 0.60, meaning its 60% of variance is explained by its predictors (BP, CSF, and BT). On the other hand, the R^2 for Baseline Plan (BP) is 0.21 which gives implications that 21% of BP variance is explained by Technical Skills of the Project controller (TSPC). Project Mission Success (PMS) has the highest explanatory power in the model with an R^2 of 0.81 and the variance accounted for by project success represents 81%. The low R^2 of 0.05 for PCS indicates that improvement in compliance success calls for consideration of the external regulatory elements in predictive models.

In sum, the model shows that Blockchain Technology is effective in improving project success in terms of its impact on Critical Success Factors (CSFs) and Baseline Planning (BP). In addition, the contribution of Technical Expertise greatly enhances structured planning and hence creates a positive impact on project efficiency. Results show that Project Success greatly affects Mission Success whereas it has a limited impact on Compliance Success, which means that more external regulatory factors must be accounted for in further studies. These outcomes provide practical guidance for facilitating optimum blockchain adoption in the engineering project management systems while also ensuring high levels of operational performance and regulatory compliance.

Discussion

The results of this study provide substantial breakthroughs to theoretical frameworks, academic research, and practical implementations with respect to blockchain-based engineering project control systems for the chemical sector. The research validates that BT contributes directly to PS by influencing PS through CSFs and BP. These outcomes are in line with and extend current theories in project management, such as institutional theory and compliance governance models, by demonstrating how innovations in technology affect project efficiency and strategic outcomes (David et al., 2025; Jawad, Ledwith, & Khan, 2024). Jawad, Ledwith, & Khan,

2024). Giving more color to the existing research on digital transformation in project management, this study enhances the notion that blockchain enhances risk mitigation, operational transparency, and automation that are vital for improving project efficiency, project mission success (Amies, Jin, & Senaratne, 2025). Practically speaking, the study reveals the need for technical skills and systematic planning for project success, implying a data-informed approach to the introduction of blockchain into the engineering control systems.

However, the study shows inconsistency with some theoretical perspectives, specifically, with compliance governance models.<< Institutional theory predicts technology will enhance compliance with norms but the study findings expose that Project Compliance Success (PCS) is not significantly impacted by blockchain implementation or the level of project execution. This means that external compliance control, legal securities, and policy frameworks have more influence over the compliance outcomes thus indicating lack of consideration over these aspects in the prevailing technology based compliance thinking (Saberi et al., 2019). Future exploration should involve compliance governance frameworks to examine the impact of external regulatory bodies to blockchain's workability in facilitating the compliance with projects.

The results of the present study confirm the findings of past research that emphasize the capabilities of blockchain to enhance transparency, automation, and effectiveness in project management, emphasizing its critical contributions to digital transformation processes in project management (David et al., 2025). A remarkable positive relationship ($r = 0.810$, $p < .01$) was found between the adoption of blockchain and CSFs, as established in the study's previous work emphasizing the role of blockchain in operational risk management and process optimization (Jawad, Ledwith, & Khan, 2024). In addition, the research supports the fact that technical acumen has a serious bearing on the baseline planning to influence project achievement, where structured planning plans are known to strengthen execution outcomes (Amies, Jin, & Senaratne 2025).

Conclusion

This research design provides great perspectives as far as the contribution of Blockchain Technology (BT) to engineering project control systems are concerned and is specifically directed towards the chemical industry. This study validates that blockchain indirectly enhances project success by improving the way Critical Success Factors (CSFs) and Baseline Planning (BP) are managed, and that the technology should be blended with systematic planning and risk management strategies (David et al., 2025; Jawad, Ledwith, & Khan, 2024). The findings highlight the importance of technical proficiency in project management for creating successful baseline planning that has a significant impact on the results of project implementation. This research contributes to the body of knowledge in project management and compliance governance, noting that three factors, technological innovations, organizational planning and project outcomes, are interdependent (Amies, Jin, & Senaratne, 2025).

Theoretical insights indicate that this research expands on prior studies of institutional theory and compliance governance through

demonstrating the way the blending of blockchain and project control mechanisms and CSFs defines its influence on project success (Saberi et al., 2019). The existing research primarily focuses on the implementation of blockchain in financial transactions, supply chains, and contract automation, although this study broadens the topic to engineering project management, presenting a unique view on how digital transformation impacts projects (Kamble et al., 2019). Moreover, the research demonstrates that the effect of blockchain technology or results of project operational practices on compliance outcomes is minor, which means that the compliance effectiveness is primarily driven by external regulations and enforcement strategies (David et al., 2025).

The research further emphasizes that for companies using blockchain-based project management systems, structured planning and an increase in the employees' skills are very important in leveraging all the benefits of blockchain. Businesses that focus on technical training of project controllers, use standardized planning frameworks, and establish digital monitoring mechanisms find it easier to find success in their projects and better missions (Jawad, Ledwith, & Khan, 2024). Although the correlation between project success and compliance success is not significant, companies seeking to improve compliance results must emphasize cooperation with regulatory authorities, industry auditors, and legal governance entities rather than focusing on technology upgrades (Amies, Jin, & Senaratne, 2025).

The Future Research Direction and Praxis Guidelines for Organizations

The study provides valuable insight about the application of blockchain in engineering project control but also highlights research and managerial practices opportunities for further development. One of the most important areas for further research lies in an exploration of external compliance mechanisms within the context of project management enabled through the blockchain. The research revealed that project compliance success (PCS) insignificantly depends on blockchain or intramural execution strategies, where external regulatory mechanisms and enforcement are dominant (David et al., 2025; Jawad, Ledwith, & Khan, 2024). Jawad, Ledwith, & Khan, 2024). Moreover, future research should have legal frameworks and regulatory oversight as well as audit procedures as the elements of comprehensive view of the success of compliance. Additionally, expanding the analysis to incorporate sectors such as construction, oil and gas, and infrastructure development will provide a clearer eye on how blockchain may benefit organizations from all industries (Amies, Jin, & Senaratne, 2025).

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