Research on Collaborative Mechanisms and Efficiency in Construction Project Supply Chains Driven by Shared Digital Platforms

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Abstract: Addressing the issue of inconsistent application outcomes for shared digital platforms in construction projects, this study aims to uncover the intrinsic relationship and underlying mechanisms linking platform usage to project success. A multidimensional mediation model was constructed, encompassing 'platform usage-collaborative mechanisms-project effectiveness'. Empirical analysis was conducted on 300 valid questionnaires from frontline project managers, with mediating effects verified using the SPSS PROCESS macro. Findings indicate: Firstly, differentiated platform usage patterns exert distinct effects on collaborative mechanisms. Collaborative usage significantly fosters cross-organizational trust and interactive memory, whereas instrumental usage primarily enhances workflow integration. Secondly, three collaborative mechanisms play pivotal mediating roles between platform usage and project effectiveness. Specifically, platforms deliver value through three pathways: 1) Collaborative usage elevates stakeholder satisfaction by cultivating cross-organizational trust; 2) Collaborative use enhances project innovation and adaptability by establishing cross-organizational interactive memory; 3) Instrumental use safeguards project efficiency and quality by strengthening workflow integration. This study reveals the intrinsic link between platform empowerment and project success, demonstrating that how a platform is used matters more than whether it is used at all. Furthermore, relational, cognitive, and process mechanisms serve as the critical bridge connecting technology and effectiveness.

Keywords: Shared Digital Platform; Comprehensive Project Effectiveness; Collaborative Mechanisms; Mediation Effect; Temporary Multi-Organization (TMO)

1. Introduction

Within the current national strategy of vigorously advancing the digital economy and new infrastructure, the construction industry-as a pillar of the national economy-has seen its digital transformation and high-quality development become a crucial component in achieving the nation's modernization goals. Traditional construction practices face numerous challenges, including efficiency bottlenecks, resource wastage, and rudimentary management. Consequently, propelling the sector's shift from factor-driven to innovation-driven growth, and leveraging next-generation information technologies to reshape its industrial ecosystem, represents not only an intrinsic imperative for the construction industry's own advancement but also a vital measure serving the nation's overarching development strategy.

Focusing on construction projects themselves, their supply chains exhibit the typical characteristics of a 'temporary multi-organization (TMO)' structure. This refers to a complex network formed ad hoc by multiple independent entities-including owners, designers, main contractors, subcontractors, and suppliers-for specific tasks [1]. This inherent temporariness and cross-organizational nature inevitably leads to collaboration challenges such as organizational barriers, information silos, and trust deficits. As Fan Jinlong observes, even with the introduction of advanced BIM technology, 'data collaboration barriers' throughout the project lifecycle remain the core bottleneck constraining project success.[2]

Shared digital platforms serve as pivotal vehicles for implementing BIM concepts, offering unprecedented technical possibilities for breaking down information barriers and fostering multi-party collaboration [3]. However, in practice, the introduction of such platforms does not necessarily translate to enhanced

collaborative efficiency. Numerous projects have incurred substantial investment yet yielded suboptimal results, sometimes even increasing communication burdens. This highlights a core management issue: there exists an intrinsic relationship between technological potential and project effectiveness. Specifically, through which specific intermediary processes (collaborative mechanisms) does the platform ultimately influence performance? Consequently, the central research question is: how precisely does the shared digital platform drive multi-party collaboration across the construction project supply chain, thereby enhancing overall project effectiveness?

2. Literature Review

2.1 Use of Shared Digital Platforms

As the core vehicle for digital transformation within the construction industry, shared digital platforms have become a focal point of academic attention. Early research predominantly centered on establishing their technical frameworks, such as Succar's BIM framework, which provided a foundational research and delivery paradigm for stakeholders in the construction project sector. However, the practical implementation of these platforms has not met expectations [3]. Domestic scholar Fan Jinlong astutely highlighted the formidable challenges and standardization pathways for autonomous BIM platforms in achieving data interoperability throughout the project lifecycle [2]. These studies underscore the complexity of technical implementation and data integration. Yet existing literature predominantly remains confined to discussions of the platform's 'technical capabilities' or 'adoption willingness'. Consequently, academic attention to how the platform is utilized at the organizational level and its differentiated impacts remains insufficient, with existing research lacking a nuanced perspective grounded in actual application behaviors.

2.2 Project Supply Chain Collaboration Mechanism

The utilization of the platform must pass through a series of intermediary mechanisms before ultimately impacting project performance; these mechanisms may be summarized as the 'project supply chain collaboration mechanism'. Construction projects, as prototypical temporary multi-organization (TMO) endeavors, rely heavily on effective coordination among all parties within the supply chain for their success [1]. Saukko proposed an integrated capability framework encompassing three dimensions-relationships, cognition, and processes-providing a robust theoretical perspective for understanding complex cross-organizational collaboration [4]. At the process mechanism level, Fawcett's three-stage supply chain collaboration implementation model offers insights into the evolutionary pathways of information sharing and workflow integration [5]. Regarding cognitive mechanisms, Ratcheva's research emphasizes the importance of integrating heterogeneous knowledge through boundary-spanning processes, aligning with Fu Jindi's validated notion that 'interactive memory' empowers team capabilities [6,7]. Regarding relational mechanisms, blockchain applications in construction indirectly corroborate technology's pivotal role in reconfiguring cross-organizational trust [8,9]. While existing literature acknowledges collaboration's significance, no study has systematically integrated these three mechanisms within a unified framework to examine their specific manifestations and interactions within the enabling environment of shared digital platforms [10].

2.3 Project Overall Effectiveness

Collaboration in construction projects should be directed towards enhancing overall project effectiveness. Traditional measures of project success primarily focus on the iron triangle of cost, time and quality. However, Atkinson contends that this evaluation framework is overly narrow and must incorporate broader, more diverse criteria such as stakeholder satisfaction [11]. As project complexity and environmental uncertainty increase, a team's dynamic capacity to respond to unforeseen circumstances has increasingly become a key measure of project success. Xu Guang's research on the mechanisms inducing 'organizational improvisation' within the stage creative process provides a robust theoretical foundation for understanding a project's 'innovation and adaptability' [12]. This indicates that comprehensively assessing the ultimate value of shared digital platform applications requires a comprehensive effectiveness evaluation system that transcends traditional performance metrics-an approach yet to be widely adopted in

existing research.

2.4 Literature Review and Research Gaps

In summary, existing literature provides a crucial theoretical foundation for understanding digital platforms, collaborative mechanisms, and project effectiveness, yet it also exhibits notable shortcomings. Firstly, platform research has predominantly focused on technical functionality rather than differentiated usage behaviors. Secondly, while the exploration of collaborative mechanisms has been thorough, it lacks an integrated framework to examine their concurrent effects within digital platform environments. Finally, evaluations of project effectiveness remain prone to relying on traditional metrics. These theoretical gaps collectively underscore the necessity for further research.

3. Research Design

3.1 Research Model Construction

Building upon the limitations of prior research, this study constructs a mediation effect model incorporating independent variables, mediating variables, and dependent variables to systematically elucidate the intrinsic operational mechanisms underlying the utilization of shared digital platforms. The core logic of this model posits that differentiated usage behaviors of shared digital platforms do not exert a direct influence upon project outcomes. Instead, they impact the overall effectiveness of projects by fostering a series of critical cross-organizational collaborative mechanisms.

3.2 Formulation of Research Hypotheses

Based on the aforementioned research model and theoretical deductions, this study proposes that the utilization of shared digital platforms exerts a significant positive influence on the collaborative mechanisms within project supply chains (H1); that the collaborative mechanisms within project supply chains exert a significant positive influence on project overall effectiveness (H2); and finally, that the collaborative mechanisms within project supply chains play a crucial mediating role between the utilization of shared digital platforms and project overall effectiveness (H3). Specifically, the collaborative use of platforms is anticipated to exert a stronger positive influence on relational mechanisms (cross-organizational trust) and cognitive mechanisms (cross-organizational interaction memory) (H1a, H1b), whilst instrumental use significantly impacts process mechanisms (workflow integration) (H1c). Concurrently, relational mechanisms are projected to positively influence stakeholder satisfaction (H2a), cognitive mechanisms affect project innovation and adaptability (H2b), while process mechanisms impact project efficiency and quality (H2c).

3.3 Variable Measurement and Questionnaire Design

To test the aforementioned hypotheses, this study employed a questionnaire survey method for data collection. The questionnaire design comprised two principal sections: the first gathered basic information on respondents and projects, while the second featured the main scales measuring core variables within the model. Beyond basic information, all main scales were measured using a 7-point Likert scale. All scale items were adapted for the specific context of construction projects, drawing upon authoritative established scales. The independent variable 'shared digital platform usage' was adapted from Fu Jindi, distinguishing between 'instrumental usage' measuring routine work behaviors and 'collaborative usage' measuring non-routine interactive behaviors [6]. The mediating variable 'project supply chain collaboration mechanism' draws upon Saukko's framework, operationalized into three dimensions adapted from relevant supply chain research: 'inter-organizational trust' (adapted from Saukko); 'cognitive mechanism: inter-organizational interaction memory' (adapted from Fu Jindi); and 'process mechanism: workflow integration' (adapted from Fawcett) [4–6]. The dependent variable 'project overall effectiveness' draws upon the advocacy of Atkinson et al., establishing a comprehensive evaluation system encompassing 'project efficiency and quality' 'stakeholder satisfaction' and 'innovation and adaptability' (adapted from Xu Guang and Fu Jindi) [6,11,12]. Additionally, the questionnaire collected information on project roles, company type, and investment scale as control variables for subsequent analysis.

4. Data Analysis and Empirical Findings

4.1 Sample Description

The subjects of this study comprised project

managers and core technical personnel in China who had participated in construction projects and possessed experience using shared digital platforms. To ensure sample representativeness, data collection was conducted via online questionnaires through multiple channels including industry conferences, alumni networks, and specialized construction industry communities. Prior to distribution, the questionnaire underwent pre-testing, with minor adjustments made to certain items based on feedback. A total of 300 questionnaires were distributed. After excluding invalid responses, 300 valid questionnaires were ultimately recovered, achieving a 100.0% valid response rate.

4.2 Reliability and Validity Analysis

For the collected data, this study will employ the social science statistical software package SPSS 26.0 as the primary analytical tool. The analysis process will commence with descriptive statistical analysis to present the sample's fundamental information and the overall distribution of each variable. Subsequently, rigorous reliability and validity tests will be conducted, assessing the scale's measurement quality through Cronbach's alpha and examining its structural validity via exploratory factor analysis (EFA).

Specifically, regarding independent variables: For the mediating variables, the Cronbach's Alpha coefficient for cross-organizational trust was 0.875, for cross-organizational interactive memory 0.871, and for workflow integration 0.885; For the dependent variables, the Cronbach's Alpha coefficient for project efficiency and quality was 0.825, that for stakeholder satisfaction was 0.864, and that for innovation and adaptability was 0.831.

In summary, all scales in this study demonstrated sound reliability, indicating high internal consistency and dependability of the questionnaire. The data quality is suitable for subsequent correlation and mediation effect analyzes.

4.3 Mediation Analysis

To test the proposed mediation hypothesis (H3) in this study, the SPSS PROCESS macro developed by Hayes (2022) (Model 4) was employed. The mediation model was examined using bootstrapping (5,000 repeated samples), with particular focus on the 95% confidence intervals for indirect effects to determine the significance of the mediating effect. The test results are presented in Table 1 to 3.

First, concerning the relational mechanism pathway (collaborative use → cross-organizational trust → stakeholder satisfaction), results indicate that cross-organizational trust exhibits a significant indirect effect between collaborative use and stakeholder satisfaction (effect=0.1533, 95% Bootstrapping CI = [0.1001,0.2138]). As this confidence interval does not contain zero, the mediating effect is established.

Table 1. Relational Mechanism

Path	Coeff	Effect	P-Value	95%CI
H1a(X->Y)	0.4482	-	P<0.001	-
H2a(M->Y)	0.3420	-	P<0.001	-
H3a(X->M->Y)	-	0.1533	-	[0.1001,0.2138]

Secondly, concerning the cognitive mechanism pathway (collaborative use → cross-organizational interaction memory → innovation and adaptability), results indicate that cross-organizational interaction memory exhibits a significant indirect effect between collaborative use and project innovation and adaptability (effect=0.1429, 95% Bootstrapping CI = [0.0925,0.1995]). This confidence interval likewise excludes zero, confirming the mediating effect.

Table 2. Cognitive Mechanism

Path	Coeff	Effect	P-Value	95%CI
H1b(X->Y)	0.3715	-	P<0.001	-
H2b(M->Y)	0.3846	-	P<0.001	-
H3b(X->M->Y)	-	0.1429	-	[0.0925,0.1995]

Finally, regarding the process mechanism pathway (instrumental use → workflow integration → project efficiency and quality), results indicate that workflow integration exhibits a significant indirect effect between instrumental use and project efficiency and quality (effect=0.1513, 95% Bootstrapping CI = [0.0913,0.2194]). This confidence interval excludes zero, confirming the mediating effect.

Table 3. Process Mechanism

Path	Coeff	Effect	P-Value	95%CI
H1c(X->Y)	0.4288	-	P<0.0.01	-
H2c(M->Y)	0.3529	-	P<0.001	-
H3c(X->M->Y)	-	0.1513	-	[0.0913,0.2194]

In summary, all three core mediating pathways proposed in this study received robust empirical support. This confirms that project supply chain coordination mechanisms (relational, cognitive, and process-based) indeed play a pivotal mediating role between shared digital platform usage and overall project effectiveness. The

overarching hypothesis H3 of this study is fully validated.

5. Conclusion

5.1 Research Findings

This study aims to uncover the intrinsic linkages between shared digital platforms and the success of construction projects. By constructing and testing a mediating effects model of 'platform usage-collaborative mechanisms-project effectiveness', it systematically reveals the underlying operational mechanisms of shared digital platforms within temporary multi-organization (TMO) environments. Following rigorous statistical analysis of 300 valid questionnaire responses, the core hypotheses were validated, yielding the following principal findings.

Firstly, the study confirms that the manner of using shared digital platforms is far more critical than mere usage itself. Findings clearly demonstrate differentiated effects of platform utilization: 'collaborative usage'-characterized by resolving ad hoc issues and knowledge sharing-serves as the core driver for fostering collaborative mechanisms such as cross-organizational trust and interactive memory. Conversely, 'instrumental usage'-defined by completing procedural tasks-primarily influences the collaborative mechanism of workflow integration. This conclusion challenges the stereotype of platforms as homogeneous technological tools, offering a more nuanced perspective on understanding the interaction between technology and organizational behavior.

Secondly, this study validated the pivotal bridging role of project supply chain coordination mechanisms between platform usage and project effectiveness. Empirical findings indicate that shared digital platforms do not directly enhance project effectiveness but realize their value through three distinct mediating pathways: collaborative usage fosters cross-organizational trust, thereby increasing stakeholder satisfaction; collaborative usage establishes cross-organizational interactive memory, enhancing project innovation and adaptability; instrumental usage strengthens workflow integration, ensuring project efficiency and quality. This discovery demonstrates that the three core collaborative mechanisms-relationship, cognition, and process-constitute the pivotal link connecting technological investment to project success.

5.2 Theoretical Contributions and Practical Implications

The findings of this study hold significant theoretical and practical implications. Theoretically, it successfully extends and validates Fu Jindi's theory of interactive memory-originally verified within a single enterprise-to the more complex context of cross-organizational engineering projects. Concurrently, by integrating Saukko's integrative capability framework with Atkinson's multiple success criteria, this research constructs and tests a more comprehensive mediation model, thereby deepening our understanding of the mechanisms underlying digital technology adoption within temporary multi-organizational environments. Practically, this research offers clear management insights for engineering project leaders: they should not solely focus on platform deployment and usage rates, but rather provide differentiated usage guidance aligned with project objectives. Where innovation and adaptability are paramount, fostering an open communication culture and encouraging collaborative tool usage is essential. Conversely, when efficiency and quality are core goals, prioritizing standardized instrumental usage and seamless process integration becomes critical. Ultimately, this research demonstrates that investing in seemingly intangible mechanisms-such as fostering trust and promoting knowledge sharing-constitutes the critical factor in translating technological potential into project success.

5.3 Research Limitations and Future Prospectsz

This study also has certain limitations. Firstly, the use of cross-sectional data, while revealing strong correlations between variables, makes it difficult to fully establish causality. Future research could employ longitudinal tracking or case studies to deepen understanding. Secondly, the sample primarily focuses on China, and the generalisability of the findings requires testing across broader cultural and institutional contexts. Finally, this study did not account for potential moderating variables such as contract types or project scale. Future research could further explore how such contextual factors influence the effectiveness of platform utilization.

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