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Research on Supply Chain Quality Management Mechanisms in Construction Enterprises Enabled by Information Technology

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Abstract. In response to the inefficiency of quality control in construction supply chains due to information asymmetry and multi-stakeholder collaboration difficulties in the context of the digital economy, this study constructs a chain-mediated model of "information technology empowerment—supply chain transparency—quality collaborative behavior—quality performance" based on information processing theory and transaction cost theory. Using survey data from 286 general contractors and their core suppliers in the construction industry, the intrinsic mechanism was empirically tested using structural equation modeling (SEM). The results show that: (1) Information technology empowerment significantly enhances the transparency of the construction supply chain, serving as a prerequisite driver for expanding organizational information processing capabilities; (2) Supply chain transparency, as an effective governance mechanism, significantly stimulates quality collaborative behaviors among supply chain members (including in-depth quality management practices and supplier-specific investments); (3) Supply chain transparency and quality collaborative behavior play a complete chain-mediated role between information technology empowerment and quality performance, revealing the path logic that technological investment must be transformed into a transparent information environment and substantive collaborative behaviors to improve performance; (4) Perceived organizational support plays a significant positive moderating role in the impact of information technology empowerment on supply chain transparency. This study not only enriches the theoretical perspective of supply chain quality management but also provides management insights for construction enterprises to achieve "quality governance through data" by establishing a full-link data-driven early warning mechanism and a visualized incentive mechanism.

Keywords: Construction enterprises; Information technology empowerment; Supply chain transparency; Quality collaborative behavior

1. Introduction

The digital economy is the third major economic form spawned by a new round of information technology revolution, capable of promoting high-quality economic development from multiple levels such as technology, elements, innovation, and integration. In the context of the digital economy, new-generation digital technologies represented by artificial intelligence, big data, the Internet of Things, fifth-generation mobile communication, and blockchain are accelerating their comprehensive integration and penetration into various industries. In the field of engineering construction, developed countries have successively released digital technology-based construction industry development strategies, such as the "Infrastructure Reconstruction Strategic Plan" (USA), "Construction 2025" strategy (UK), and "Construction Site Productivity Revolution" strategy (Japan). As a pillar industry of the national economy, the digitalization level of the construction industry has long lagged. According to a McKinsey Global Institute report, the average annual growth rate of labor productivity in the global construction industry is only about 1%, far lower than the 3.6% in manufacturing, and rework costs due to poor supply chain coordination and ineffective quality control account for an average of 5% to 12% of the total project investment (Agarwal et al., 2016; Love et al., 2019). The key to the inefficiency in the construction industry is its highly complex supply chain and diversified participating entities, leading to information asymmetry and collaboration difficulties. Although BIM, IoT, and other information technologies have great application potential, in actual engineering practice, data silos still hinder the effective penetration of quality information, resulting in inefficient cross-organizational quality control (Mojumder & Singh, 2021). According to Information Processing Theory, organizations need to invest in information systems to enhance their information processing capabilities to match the uncertainty of internal and external environments, and this enhancement is crucial for handling complex supply chain information (Wickens & Carswell, 2021). At the same time, Transaction Cost Theory points out that a high level of asset specificity is usually accompanied by dependence on trading partners, requiring a tighter governance structure to curb opportunistic behavior, and an effective information sharing mechanism is key to reducing transaction costs, preventing "hold-up" problems, and promoting long-term cooperative relationships among supply chain members (Cuypers et al., 2021). However, there is a general lack of transparent trust mechanisms in the current construction supply chain, leading to unclear quality responsibility and slow response to rectification. Therefore, this study focuses on how to use emerging information technologies to break data silos and reshape the supply chain quality governance system. Solving this problem has practical urgency for reducing industry quality losses amounting to hundreds of billions, improving construction project quality, and enhancing the performance of industry digital transformation.

This study aims to reveal the intrinsic mechanism of information technology empowerment on the quality management performance of construction supply chains and to construct corresponding management optimization mechanisms, in order to enrich the application scope of existing theories in the context of digital quality governance in the construction industry. Theoretically, this study introduces information processing theory and transaction cost theory into construction supply chain research, empirically examining how supply chain information sharing, as a key antecedent variable, significantly and positively influences quality management practices and supplier-specific investments, thereby effectively enhancing enterprises' innovation performance and market share performance. Evidence from manufacturing supply chains also demonstrates that digital informatics systems not only enhance service quality but also drive logistics efficiency and create sustainable competitive advantages through improved supply chain coordination (Simanjuntak et al., 2025) Practically, the research results will provide construction enterprises with a set of "data-driven quality governance" operational guidelines, helping managers effectively utilize information technology to improve supply chain transparency and solve multi-stakeholder collaboration difficulties by designing data-driven quality early warning and incentive-compatible mechanisms. This has significant guiding implications for strengthening social connections among supply chain members, ensuring long-term economic benefits for enterprises, and ultimately achieving economic and social sustainability for construction enterprises.

This study follows the “literature review—theoretical deduction—empirical testing—mechanism construction” research paradigm, aiming to analyze the operational mechanism of quality management in construction supply chains empowered by information technology. First, by reviewing existing literature, a chain conceptual model encompassing information technology empowerment, supply chain transparency, quality collaborative behavior, and quality performance is constructed; based on this, considering the project-based characteristics of the construction industry, a survey questionnaire is selected to primarily explore the intrinsic incentive mechanism of information technology-driven supply chain information integration on quality management practices and relationship-specific investments (Devaraj et al., 2007; Zhou & Benton, 2007). Second, structural equation modeling (SEM) is used to infer sample survey data, measure the mediating effect of supply chain transparency and the boundary moderating conditions of organizational support, and construct a competitive model following the structural equation modeling paradigm to cross-validate the robustness and explanatory power of the theoretical model from a multi-dimensional perspective (Anderson & Gerbing, 1988). Finally, based on the logical extension of empirical results, a digital supply chain quality governance operating mechanism is designed from two dimensions: cross-organizational process standardization and visualized incentive compatibility.

2. Theoretical Basis and Literature Review

2.1.Theoretical Basis

2.1.1 Information Processing Theory

Information processing theory, proposed by Galbraith, posits that organizational effectiveness hinges on the dynamic alignment between "information processing requirements" and "information processing capabilities" (Galbraith, 1973). In the context of construction supply chains, the high degree of project customization, numerous stakeholders, and the unpredictability of construction sites collectively create extreme environmental uncertainty, compelling companies to process vast amounts of heterogeneous data. If information processing capabilities lag, it can lead to delayed decision-making and ineffective quality control. With the development of the digital economy, recent research has further expanded the boundaries of this theory, indicating that digital technologies, represented by artificial intelligence and big data, are not merely auxiliary tools but "vertical information systems" that extend the cognitive boundaries of organizations (Pan et al., 2025). Particularly when companies face sudden risks such as supply disruptions or quality crises, the advanced analytical capabilities based on digital technology can significantly enhance supply chain visibility and early warning capabilities, transforming passive responses into proactive sensing (Yuan& Li, 2022). Technology-enabled information integration capabilities are critical organizational assets for maintaining supply chain resilience and agility in a VUCA (Volatile, Uncertain, Complex, Ambiguous) environment (Stroumpoulis& Kopanaki, 2022). A systematic literature review in the food supply chain domain also validates that big data analytics serves as a critical enabler for enhancing supply chain agility and performance through the development of dynamic capabilities, despite implementation challenges (Le & Dam, 2025). Empirical research in the Indonesian courier industry also confirms that technology investments significantly enhance supply chain agility, which serves as a critical mediating pathway for improving supply chain performance (Syafrianita et al., 2025). This study argues that information technology empowerment greatly expands the information processing bandwidth of construction supply chains, addressing the problem of quality governance failure caused by information overload and fragmentation in traditional models.

2.1.2 Transaction Cost Theory

Transaction cost theory offers an economic perspective for understanding inter-organizational governance structures and cooperative behaviors. Asset specificity, uncertainty, and transaction frequency are the three key dimensions determining transaction costs and the choice of governance modes (Williamson, 1975). In construction projects, suppliers often need to make specific equipment investments or process adjustments to meet the quality standards of the general contractor. High levels of asset specificity can easily lead to "hold-up" risks and opportunistic behavior, thereby increasing supervision and negotiation costs. However, digital transformation is reshaping the application context of this theory. Research indicates that digital platforms and blockchain technology significantly reduce external transaction costs such as searching, bargaining, and performance by providing immutable transaction records and standardized smart contracts (Wu & Yu, 2023). The "technology-based trust mechanism" established by digital platforms can effectively curb opportunistic behavior, thereby to some extent replacing expensive hierarchical governance, allowing companies to achieve close inter-organizational collaboration with lower governance costs even in situations of high asset specificity. Digital trust mechanisms can blur organizational boundaries, prompting supply chain partners to shift from zero-sum games to long-term value-based quality collaboration (Roeck et al., 2020).

2.2.Information Technology Empowerment and Supply Chain Transparency

Supply chain transparency not only involves the breadth of inter-organizational information exchange but also concerns the depth and quality of data penetration, i.e., whether real-time visualization and full-process traceability across organizational boundaries can be achieved. In the context of construction supply chains, information technology empowerment is defined as the breadth of digital technology application and the depth of data integration in supply chain management. Existing research indicates that the interconnectedness of enterprise systems is the infrastructure supporting supply chain collaborative operations. Through the deep application of technologies such as BIM, IoT, and cloud computing, enterprises can significantly enhance their ability to generate, disseminate, and process complex operational information (Zdravković et al., 2022; Wu et al., 2024). Empirical research in the energy construction sector further confirms that integrating digital technologies such as IoT and AI into quality assurance processes significantly reduces defect risks and optimizes long-term equipment operational costs (Grigaravičius, 2025). According to information processing theory, in the face of the high uncertainty of construction projects, simple organizational structure adjustments are insufficient to meet the vast information processing demands; advanced information technology must be relied upon to expand "organizational cognitive bandwidth" (Galbraith, 1973). Research confirms that effective information sharing technology support is a key antecedent for achieving supply chain integration, breaking down traditional "information silos" and enabling early and accurate identification of quality defects, schedule deviations, and potential risks (Prajogo& Olhager, 2012). For construction enterprises, technological empowerment reduces the marginal cost of information acquisition, allowing general contractors and subcontractors to synchronize key process parameters and material statuses in real time. Therefore, the level of technological investment directly determines the information carrying capacity and interaction efficiency of the supply chain, serving as the physical foundation and prior driving force for building a highly transparent supply chain network.Thus, the following hypothesis is proposed:

H1: In construction enterprises, information technology empowerment has a significant positive impact on supply chain transparency.

2.3.Supply Chain Transparency and Quality Collaboration Behavior

The enhancement of supply chain transparency is the core mechanism that triggers inter-organizational quality collaborative behavior, which specifically manifests as deep joint quality management practices and relationship-specific investments by suppliers. Firstly, a high level of supply chain transparency provides a data foundation for quality management. Research shows that when core enterprises and suppliers achieve information integration, both parties can conduct statistical process control (SPC) based on shared quality data and establish cross-organizational quality improvement teams, thereby extending internal quality management to the entire supply chain network (Li et al., 2011). Secondly, according to transaction cost theory and the relational perspective, information transparency can effectively curb opportunistic behavior and alleviate suppliers' concerns about the "lock-in" risk that may arise from asset-specific investments (Grover & Malhotra, 2003). When suppliers perceive that the relationship between the two parties is transparent and observable, they are more inclined to make specific investments, such as purchasing specialized equipment or modifying production lines, to adapt to the buyer's customized needs, because this transparent mechanism itself is an efficient governance tool that reduces the uncertainty of contract execution (Yeung et al., 2013). Conversely, in an information black box environment, suppliers, out of risk aversion, often only maintain a minimum level of general services. Therefore, supply chain transparency not only optimizes collaborative processes but also reshapes the trust structure, incentivizing supply chain partners to actively invest resources in quality collaboration. This leads to the following hypothesis:

H2: In construction enterprises, supply chain transparency has a significant positive impact on quality collaborative behavior.

2.4.Quality Collaborative Behavior and Quality Performance

Quality collaborative behavior, defined as deep quality management practices among supply chain members and relationship-specific investments by suppliers, is a direct driver for improving the quality performance of construction enterprises. Quality management theory emphasizes reducing waste through full participation and process improvement. Existing empirical research shows that effective quality management practices can significantly improve product quality, enhance customer satisfaction, and ultimately increase enterprises' market share (Kaynak, 2003). At the same time, suppliers' specific investments can reduce errors in design and production by increasing the compatibility of production tools, significantly shorten the development cycle of new products or services, and reduce overall development costs (Yeung et al., 2013). Applying this logic to the construction supply chain context, collaborative behavior means that general contractors and subcontractors achieve deep integration of quality planning in the early stages of a project. By sharing specialized resources and unifying quality standards, they can effectively reduce common quality defects and rework rates in engineering entities, and significantly improve the response speed to quality rectification requirements. Furthermore, research confirms that both hard quality control technologies and soft supplier collaboration inputs have a significant positive impact on enterprises' innovation performance and market performance (Zeng et al., 2015; Zhou & Li, 2020). Evidence from Chinese logistics services also indicates that supply chain collaboration is a core driver of innovation performance, and its effects are further amplified when combined with internal organizational capabilities (Ou et al., 2025). Additionally, a recent scientometric analysis indicates that quality management research in the construction industry is undergoing a paradigm shift from a process-centric focus to a human-centric one, emphasizing the critical role of employee satisfaction and leadership in driving organizational effectiveness (Wang et al., 2025). Therefore, when construction supply chain members form a quality collaborative relationship, their performance in terms of compliance, efficiency, and innovation will be significantly enhanced. This leads to the following hypothesis:

H3: In construction enterprises, quality collaborative behavior has a significant positive impact on quality performance.

2.5.Chained Mediation and the Moderating Effect of Perceived Organizational Support

Synthesizing the above logic, information technology empowerment itself does not directly translate into quality performance, but rather functions by reshaping the supply chain's information environment, i.e., transparency, and collaboration model, i.e., collaborative behavior. Constructing a chained mediation model of "information technology empowerment—supply chain transparency—quality collaborative behavior—quality performance" aims to clearly reveal the internal mechanism by which technological investment transforms into management effectiveness. According to information processing theory, investment in information systems first enhances an organization's ability to handle the uncertainty of complex environments, thereby increasing supply chain transparency (Galbraith, 1973). This transparent information environment then becomes an effective governance mechanism, stimulating the willingness of all parties in the supply chain to engage in quality management practices and reducing suppliers' concerns about the risks of specific investments, thereby promoting quality collaborative behavior (Li et al., 2011). Ultimately, it is these substantive collaborative behaviors that directly drive the improvement of quality performance. Furthermore, perceived organizational support plays a crucial boundary-moderating role in this process. Since small and medium-sized enterprises typically face resource constraints and cannot make redundant investments in all areas like large enterprises, top management's resource allocation towards specific strategic directions is critical (Zhou & Li, 2020). When there is strong resource support and policy commitment within the organization for digital transformation, enterprises can more effectively translate technological investment into actual information processing capabilities, meaning the promotional effect of information technology empowerment on supply chain transparency will be more significant. Conversely, without corresponding organizational support, mere technological accumulation struggles to truly break down inter-organizational data barriers. Based on this, hypothesis is proposed:

H4: In construction enterprises, supply chain transparency and quality collaborative behavior play a chained mediating role between information technology empowerment and quality performance.

H5: In construction enterprises, perceived organizational support positively moderates the impact of information technology empowerment on supply chain transparency.

In summary, the research model diagram is drawn as shown in Figure 1.

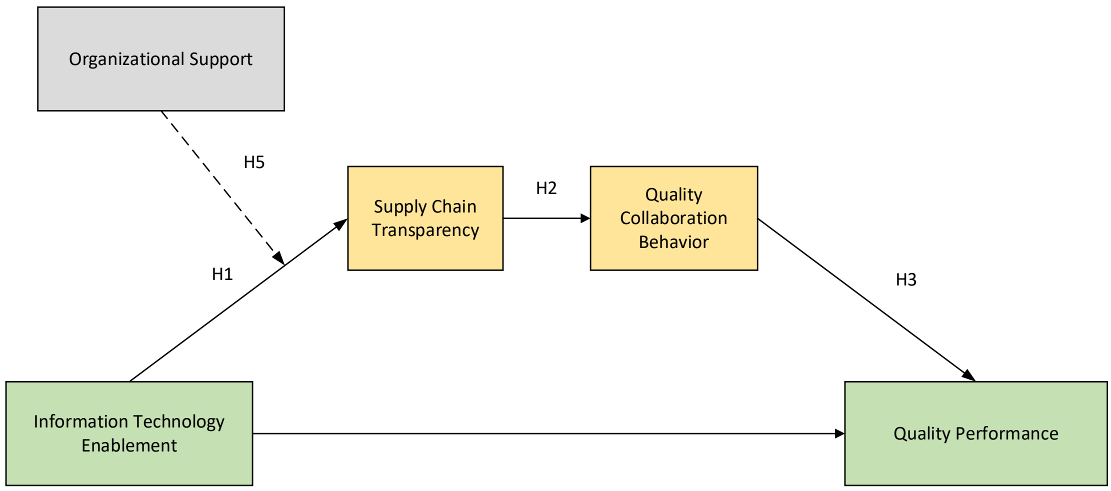

Fig.1: Research Model Diagram

3. Research Methods and Data Analysis

3.1.Data Collection

The data collection process for this study strictly followed scientific and standardized procedures to ensure the authenticity and validity of the data. The questionnaire design underwent multiple rounds of optimization, starting with a preliminary review by an expert panel comprising enterprise managers, EMBA students, and scholars. Subsequently, practicing managers were selected for pre-testing to revise semantically ambiguous items and ensure the accuracy of the measurement tool. The survey participants primarily targeted senior enterprise managers who were either pursuing or had completed an EMBA degree, including CEOs, vice presidents, department managers, and directors.Thisgroup typically possesses a deep understanding of supply chain management and quality control, along with decision-making authority. Questionnaires were distributed through various channels, and after excluding invalid samples, valid questionnaires were retained for empirical analysis. A total of 350 questionnaires were distributed, with 326 returned. After excluding invalid questionnaires due to short completion times, patterned responses, or missing key information, 286 valid questionnaires were obtained, resulting in an effective response rate of 87.7%.

The descriptive statistics of the sample enterprises are shown in Table 1. As shown in Table 1,the surveyed enterprises exhibit good representativeness and diversity, effectively reflecting the current industry landscape. In terms of years since establishment, the average lifespan of the sample enterprises is relatively long, reaching 17.5 years, which is higher than the average 3.7-year life cycle of Chinese SMEs. This indicates that the sample includes a group of successful enterprises that have achieved sustainable development amidst fierce market competition. Regarding geographical distribution, the sample broadly covers economically developed coastal provinces (e.g., Zhejiang) as well as inland provinces (e.g., Sichuan, Henan), reflecting enterprise operational characteristics in different regional economic environments. The sample enterprises span various development stages, from introduction and growth to maturity, with a larger proportion of enterprises in the growth stage, and most enterprises facing highly competitive market environments.

Table. 1: Distribution of Sample Enterprise Characteristics (N=286)

Variable	Category	Frequency	Percentage (%)
Development Stage	Introduction	60	21.0
	Growth	180	62.9
	Mature	44	15.4
	Decline	2	0.7
Geographic Location	Coastal	104	36.4
	Inland	182	63.6
Founding Years	≤10 years	82	28.7
	10–20 years	118	41.3
	≥20 years	86	30.0
Market Competition Intensity	Very Intense	174	60.8
	Intense	110	38.5
	Fair / Not Intense	2	0.7

3.2.Variable Measurement and Reliability and Validity Testing

This study employs multiple scales to operationalize core constructs such as information technology empowerment, supply chain transparency, quality collaborative behavior, and quality performance. The scale design was developed by referencing mature domestic and international literature and making necessary revisions and improvements in consideration of the construction industry context. To ensure the content validity of the survey instrument, the questionnaire underwent rigorous literature review and expert interview procedures before finalization, ensuring that the questions were accurately defined and covered key dimensions of the research area. All measurement items were assessed using a 5-point Likert scale, with endpoints set from "1-Strongly Disagree" to "5-Strongly Agree," or "1-Much Worse than Peers" to "5-Much Better than Peers," to achieve standardized measurement of respondents' subjective evaluations. Specifically, the measurement of quality performance required respondents to evaluate their company's performance relative to industry competitors, a method often used to eliminate the impact of industry heterogeneity.

To verify data quality, this study first used Cronbach's alpha coefficient and Corrected Item-Total Correlation (CITC) to test the reliability of the constructs. The results show that the Cronbach's alpha coefficients for all latent variables were above 0.8, well above the critical threshold of 0.7; at the same time, the CITC values for all measurement items exceeded 0.5, significantly higher than the minimum acceptable level, indicating that the scales have extremely high internal consistency. For validity testing, this study used Confirmatory Factor Analysis (CFA) to assess convergent validity. As shown in Table 2, the standardized factor loadings of all measurement indicators on their corresponding latent variables were greater than 0.7 and significant at the 0.001 level, meeting the basic requirement that factor loadings should be significant and greater than 0.3. The Average Variance Extracted (AVE) for each construct exceeded the recommended threshold of 0.5, and the Composite Reliability (CR) values were all above 0.6, indicating that the measurement model in this study possesses good convergent validity, and there is a high correlation between the latent variables and their measurement items.

Table.2: Reliability and Validity Analysis Results of the Measurement Model

Latent Variable	Measurement Item	Factor Loading	Cronbach's α	CR	AVE
Information Technology Enablement	ITE1: Breadth of Digital Tool Coverage	0.785	0.865	0.868	0.622
	ITE2: Cross-department Data Integration Capability	0.812			
	ITE3: Real-time Information Processing Ability	0.768			
	ITE4: Level of Intelligent Decision Support	0.788			
Supply Chain Transparency	SCT1: Visibility of Quality Standards	0.834	0.882	0.884	0.718
	SCT2: Timeliness of Key Process Parameter Sharing	0.865			
	SCT3: Transparency of Inventory Information Between Supply and Demand Sides	0.842			
Quality Collaboration Behavior	QCB1: Cross-organizational Joint Quality Improvement	0.795	0.854	0.857	0.667
	QCB2: Supplier-specific Equipment/Technology Input	0.821			
	QCB3: Joint Mechanism for Solving Quality Problems	0.833			
Quality Performance	QP1: First-pass Acceptance Rate of Projects	0.806	0.841	0.843	0.642
	QP2: Response Speed for Quality Rectification	0.792			

3.3.Discriminant Validity and Common Method Bias Test

To ensure statistical independence among latent variables, this study employed the Fornell-Larcker criterion for discriminant validity testing. This involved calculating the square root of each latent variable's AVE value and comparing it with the correlation coefficients between variables.

As shown in Table 3, the bolded values on the diagonal represent the square roots of AVE, all of which are significantly greater than other correlation coefficients in their respective rows and columns. This indicates that each construct's ability to explain its own variance is stronger than its ability to explain other constructs, confirming that the model possesses good discriminant validity. Given that all data were self-reported by a single respondent, there might be a common method bias (CMB) issue. This study used Harman's single-factor test for evaluation, placing all measurement items into an exploratory factor analysis for unrotated principal component analysis. The results showed that there were 4 factors with eigenvalues greater than 1, and the first common factor explained 32.4% of the variance, which did not exceed the critical value of 50%. The results indicate that there is no serious common method bias in the data of this study, and a single factor cannot explain most of the variance in the data, thus ensuring the reliability of subsequent structural model analysis results.

Table.3: Discriminant Validity Test Matrix

Variable	Mean	SD	ITE	SCT	QCB	QP
Information Technology Enablement（ITE）	3.85	0.76	**0.789**			
Supply Chain Transparency（SCT）	3.72	0.81	0.452	**0.847**		
Quality Collaboration Behavior（QCB）	3.94	0.69	0.386	0.512	**0.817**	
Quality Performance（QP）	4.01	0.72	0.415	0.488	0.563	**0.801**

3.4.Structural Equation Model Fitting Analysis Strategy

This study follows the two-stage analysis paradigm recommended by Anderson and Gerbing (1988), aiming to ensure the rigor and statistical power of theoretical model validation. The first stage focuses on evaluating the measurement model, i.e., before constructing causal paths, confirmatory factor analysis (CFA) is used to examine the relationship between latent variables and their measurement indicators, confirming the reliability and validity of the constructs. The second stage focuses on path analysis of the structural model, using AMOS software to build the full model to test the hypothesized relationships between latent variables. This step-by-step strategy can effectively avoid the interference of measurement errors on structural path estimation, thereby improving the accuracy of model interpretation.

Regarding the specific evaluation criteria for model fit, this study adopts Shah and Goldstein's (2006) recommendations for multi-dimensional indicator assessment, avoiding the one-sidedness of a single statistic. Specifically, this study selected three types of key fit indices: first, absolute fit indices, where, according to Browne and Cudeck's (1993) standard, a Root Mean Square Error of Approximation (RMSEA) less than 0.05 is considered a key criterion for good model fit; second, incremental fit indices, referring to Hair et al.'s (1995) suggestions, the Goodness of Fit Index (GFI), Normed Fit Index (NFI), Non-Normed Fit Index (NNFI), and Comparative Fit Index (CFI) should all exceed the threshold of 0.9; finally, parsimonious fit indices, the Normed Chi-square (χ^2/df) should be within the reasonable range of 1 to 3. Only when all the above multi-dimensional indicators meet the adaptation standards can it be concluded that the theoretical model has a good fit with the observed data.

4. Structural Model Results and Hypothesis Testing

4.1.Structural Equation Model Fit

After verifying the reliability and validity of the measurement model, this study utilized AMOS 24.0 software to construct a full structural equation model. The maximum likelihood estimation method was employed to globally assess the fit between the hypothesized model and the observed data. To overcome the potential one-sidedness of a single fit index, this study, following the recommendations of Shah and Goldstein (2006), comprehensively used absolute fit indices, incremental fit indices, and parsimonious fit indices to construct an evaluation system. Specifically selected indicators included the chi-square to degrees of freedom ratio (χ^2/df), root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), normed fit index (NFI), non-normed fit index (NNFI, also known as TLI), and comparative fit index (CFI).

The model's operational results are shown in Table 4, indicating that the theoretical model constructed in this study exhibits excellent fit performance. First, regarding parsimonious fit indices, the model's chi-square to degrees of freedom ratio (χ^2/df) is 1.583. According to the standard by Hair et al. (1995), this value falls within the theoretical range of 1 to 3, indicating good model parsimony. Second, concerning absolute fit indices, the root mean square error of approximation (RMSEA) is 0.042. Browne and Cudeck (1993) suggest that an RMSEA less than 0.05 indicates a good model fit, and this study's result fully meets this stringent standard. Concurrently, the goodness-of-fit index (GFI) is 0.934, exceeding the acceptable threshold of 0.90. Finally, for incremental fit indices, the normed fit index (NFI) is 0.945, the non-normed fit index (NNFI) is 0.966, and the comparative fit index (CFI) is as high as 0.971. All key fit indices meet or exceed statistically recommended standards, confirming a high degree of fit between the theoretical model of "information technology empowerment → supply chain transparency → quality collaborative behavior → quality performance" and the observed data. This indicates that the model construction is reasonable and provides a solid foundation for further path coefficient analysis and hypothesis testing.

Table. 4: Statistical Results of Structural Equation Model Fit Indices

Fit Index Category	Statistical Index	Criteria	Model Value	Result
Parsimonious Fit Index	χ^2/df	$1 < \chi^2/df < 3$	1.583	Good Fit
Absolute Fit Index	RMSEA	< 0.05	0.042	Good Fit
	GFI	> 0.90	0.934	Good Fit
Incremental Fit Index	CFI	> 0.90	0.971	Good Fit
	NFI	> 0.90	0.945	Good Fit
	NNFI / TLI	> 0.90	0.966	Good Fit

4.2.Path Coefficient Analysis and Research Hypothesis Testing

After confirming that the overall fit of the structural equation model meets statistical requirements, this study further estimates the path coefficients within the model to verify the research hypotheses proposed earlier. This study uses the Standardized Path Coefficient to measure the degree of influence between variables and determines the significance of the paths based on the Critical Ratio (i.e., t-value) and P-value. According to Hair et al. (1995), when the t-value is greater than 1.96, the path coefficient is significant at the 0.05 level; when the t-value is greater than 2.58, it is significant at the 0.01 level.

The results of the path analysis for the structural model are detailed in Table 5. The data shows that all three core hypothetical paths set in the model passed the significance test, and the direction of influence is consistent with theoretical expectations. The specific analysis is as follows:

The standardized path coefficient for information technology empowerment on supply chain transparency is 0.479, with a t-value of 10.916 ($p < 0.001$), reaching a highly significant level. This result strongly supports Hypothesis H1, indicating that the widespread application and deep integration of digital tools are key drivers for breaking down "information silos" in construction enterprises. This aligns with existing research conclusions that technological support can significantly promote information sharing, confirming that technological investment can effectively translate into the visualization capabilities of the supply chain network.

The influence coefficient of supply chain transparency on quality collaborative behavior is 0.779, with a t-value of 11.884 ($p < 0.001$), thus verifying Hypothesis H2. This is the path with the largest effect value in the model, indicating that the improvement of supply chain transparency plays a decisive role in stimulating cross-organizational collaboration. A transparent information environment not only reduces transaction costs but, more importantly, establishes a data-driven trust mechanism, encouraging suppliers to be more willing to make specific investments and participate in joint quality management.Thisfinding is consistent with the theoretical view that "information sharing can effectively mitigate opportunism and promote specific relationship investments."

Quality collaborative behavior shows a significant positive impact on quality performance, with a standardized path coefficient of 0.492 and a t-value of 8.607 ($p < 0.001$), thus establishing Hypothesis H3. Empirical data indicate that when deep collaborative mechanisms (such as joint improvement and resource sharing) are formed among supply chain members, they can directly translate into improvements in project entity quality and optimization of rectification efficiency. The results confirm that effective quality management practices and supplier collaboration are core drivers for enhancing enterprise innovation performance and market performance.

Table. 5: Structural Model Path Coefficients and Hypothesis Testing Results

Hypothesis	Path Relationship	S.E.	β	C.R.	P	Conclusion
H1	ITE→ SCT	0.049	0.479	10.916	***	Supported
H2	SCT→ QCB	0.058	0.779	11.884	***	Supported
H3	QCB→ QP	0.060	0.492	8.607	***	Supported

4.3.Test of Chained Mediation and Moderation Effects

To verify the validity of the "Information Technology Empowerment → Supply Chain Transparency → Quality Collaborative Behavior → Quality Performance" chained mediation path, this study employed the Bias-Corrected Percentile Bootstrap method for testing, setting the number of bootstrap samples to 5000 and the confidence level to 95%. The analysis focused on examining whether the mediation effect values of each path and their confidence intervals included 0. The data analysis results are shown in Table 6. The total indirect effect value was 0.285, and the 95% confidence interval was [0.214, 0.368], which does not include 0, indicating that the overall mediation effect is significant. Specifically, for the chained mediation path (Ind3), which is "Information technology empowerment enhances quality performance by improving supply chain transparency and then promoting quality collaborative behavior," its effect value was 0.184, and the 95% confidence interval was [0.126, 0.253]. This interval also does not include 0, and the significance test passed. This confirms that supply chain transparency and quality collaborative behavior play a complete chained transmission role between technology input and performance output, providing strong support for Hypothesis H4.

Table. 6: Bootstrap Results for Chain Mediation Effects

Path Description	Effect Type	Effect Value	Boot SE	95% CI Lower	95% CI Upper	Conclusion
Total Indirect Effect	Total Indirect	0.285	0.042	0.214	0.368	Significant
Ind1: ITE → SCT → QCB	Specific Mediation	0.373	0.051	0.285	0.482	Significant
Ind2: SCT → QCB → QP	Specific Mediation	0.383	0.054	0.288	0.496	Significant
Ind3: ITE → SCT → QCB → QP	Chain Mediation	0.184	0.033	0.126	0.253	Supported (H4)

To test the moderating effect of organizational support (OS) on the relationship between information technology empowerment and supply chain transparency (Hypothesis H5), this study constructed an interaction term "information technology empowerment × organizational support" and used hierarchical regression analysis for testing. To avoid multicollinearity, the independent and moderating variables were centered before constructing the product term. The analysis results are shown in Table 7. After controlling for main effects, the regression coefficient of the interaction term (ITE × OS) on supply chain transparency was 0.165, with a t-value of 3.428 ($p < 0.01$), indicating a significant moderating effect. To visually demonstrate the moderating pattern, this study conducted a simple slope analysis. The results showed that under conditions of high organizational support (mean + 1SD), the positive impact of information technology empowerment on supply chain transparency was significantly enhanced (Slope = 0.644, $p < 0.001$); while under conditions of low organizational support (mean - 1SD), this positive impact, although still present due to the inherent nature of the technology, was significantly weakened (Slope = 0.314, $p < 0.01$). The results validate Hypothesis H5, which states that top management's resource support and policy commitment act as "catalysts" that amplify the effects of technological empowerment, and that technological investments lacking organizational support struggle to effectively break down supply chain data barriers.

Table. 7: Moderating Effect of Organizational Support

Variable	Model 1 (Controls)	Model 2 (Main Effects)	Model 3 (Interaction)
Control Variables (Firm size, age, etc.)	Included	Included	Included
Independent Variable: IT Enablement (ITE)	—	0.452***	0.448***
Moderator: Organizational Support (OS)	—	0.315***	0.302***
Interaction: ITE × OS	—	—	0.165**
R^2	0.045	0.386	0.412
$\triangle R^2$	—	0.341***	0.026**
F Value	3.124	42.568	38.924

4.4.Competitive Model Analysis

To further verify the superiority and robustness of the "chained mediation model" proposed in this study compared to other potential theoretical explanations, this study constructs two competitive models with theoretical rationality for comparative analysis. The baseline model assumes that information technology empowerment must influence quality performance through the chained transmission of supply chain transparency and quality collaborative behavior. In contrast, competitive model 1 is constructed as a "direct effect model," assuming that information technology empowerment directly acts on quality performance, ignoring intermediate process variables, to test the validity of the "technological determinism" view; competitive model 2 is constructed as a "saturated model," adding direct paths from information technology empowerment to quality collaborative behavior and quality performance, as well as a direct path from supply chain transparency to quality performance, based on the baseline model, aiming to test whether there are direct spillover effects not captured by the theoretical model.

This study selected the chi-square to degrees of freedom ratio (χ^2/df), root mean square error of approximation (RMSEA), comparative fit index (CFI), and Akaike information criterion (AIC) as key indicators for model comparison. The data analysis results are shown in Table 8. The results indicate that the fit indices of competing model 1 were significantly worse than those of the baseline model, with its RMSEA reaching 0.078, exceeding the critical value of 0.05. This suggests that mere technological investment cannot directly explain performance improvement, and ignoring process mechanisms leads to insufficient explanatory power. Although competing model 2 performed acceptably on incremental indices such as CFI, its χ^2/df value was high, and its AIC value (512.45) was significantly higher than that of the baseline model (428.04). According to the AIC criterion, a smaller value indicates that the model achieves the best balance between fit and parsimony. Furthermore, the baseline model's RMSEA was 0.042, which was superior to competing model 2's 0.053, and all its fit indices were within the optimal range. The baseline model not only demonstrated the best statistical goodness of fit but also theoretically provided the clearest explanation of the intrinsic transmission mechanisms between variables, thus being confirmed as the optimal explanatory model for this study.

Table. 8: Comparative Analysis of Competing Model Fit Indices

Model Specification	χ^2	df	χ^2/df	RMSEA	CFI	NNFI	AIC	Conclusion
Proposed Model	268.04	165	1.624	0.042	0.971	0.966	428.04	Optimal
Competing Model 1	486.32	168	2.895	0.078	0.885	0.872	614.32	Poor Fit
Competing Model 2	355.81	162	2.196	0.053	0.942	0.938	512.45	Redundant

5. Discussion of Results and Construction of Management Mechanism

5.1.Discussion of Results

The empirical results of this study support the chain-mediated model of "information technology empowerment—supply chain transparency—quality collaborative behavior—quality performance," revealing the intrinsic mechanism by which technological investment translates into performance output. First, the analysis results confirm the significant driving effect of information technology empowerment on supply chain transparency and subsequent management behaviors, verifying the view of information processing theory that expanding information processing capabilities through technological investment is a prerequisite for addressing supply chain uncertainty and promoting cross-organizational collaboration. Second, supply chain transparency is found to significantly stimulate quality collaborative behavior, specifically manifested in promoting the deepening of quality management practices and increasing supplier-specific investments, supporting transaction cost theory, which indicates that transparent information mechanisms can serve as a governance tool to effectively mitigate opportunistic behavior, thereby reducing suppliers' perceived risk of "asset lock-in" and prompting them to invest more resources in specific relationships. Finally, the positive impact of quality collaborative behavior on quality performance indicates that both internal total quality management and external supplier-specific asset investment are direct drivers for improving innovation performance and market performance.

5.2.Design of Digital Supply Chain Quality Management Operating Mechanism for Construction Enterprises

Based on the empirical conclusion of this study that information technology empowerment significantly enhances supply chain transparency, establishing a full-link data-driven quality early warning mechanism is key to achieving "prevention in advance." To address the pain point of delayed decision-making caused by information asymmetry in the construction supply chain, enterprises should leverage IoT, mobile terminals, and BIM technology to build an integrated information processing platform for real-time collection of critical quality data on personnel, materials, machinery, and the environment. According to information processing theory, this technological investment can effectively expand the organization's ability to handle complex environmental uncertainties and break down data barriers between different levels of subcontractors. This mechanism uses algorithmic models for real-time analysis and graded early warning of heterogeneous data, ensuring that core enterprises can penetrate multi-level supply chains and promptly identify potential quality deviations and risk sources, thereby transforming traditional "post-event rectification" into "pre-event perception" and "proactive intervention," significantly improving the timeliness and accuracy of quality control. Empirical evidence from the agri-food sector further demonstrates that the deep integration of information system technologies with certified management systems significantly enhances an organization's capability to identify and mitigate operational risks (Chidoud et al., 2025).

Based on the finding of supply chain transparency promoting quality collaborative behavior in this study, the implementation of cross-organizational process standardization is the core to ensure the effective implementation of quality management practices. Research indicates that effective quality management requires full participation and process improvement, extending to both upstream and downstream supply chain partners. Construction enterprises should establish unified data interaction standards and quality operating procedures, utilizing digital collaboration platforms to internalize the general contractor's quality standards into suppliers' production specifications, thereby eliminating execution deviations caused by inconsistent standards. This standardized process not only reduces coordination costs for cross-organizational communication but also minimizes parameter omissions and errors in design solutions by increasing the commonality of production tools and equipment. Through process interoperability, supply chain members are encouraged to participate in quality planning early in the project, transitioning from internal quality control within a single enterprise to cross-enterprise joint quality improvement, thereby enhancing overall project compliance and delivery efficiency.

Building a visualization-based incentive compatibility mechanism is a guarantee for resolving "lock-in" risks and maintaining long-term cooperation momentum. Transaction cost theory points out that while high levels of asset-specific investment can lead to higher product quality and flexibility, they also increase the opportunistic risks faced by suppliers. To address this, construction enterprises should use blockchain or shared ledger technology to record suppliers' quality performance, leveraging the transparency of information sharing to curb opportunistic behavior. By establishing a credit evaluation and dynamic dividend system based on objective performance data, the transparency and observability of cooperative relationships can be enhanced, providing suppliers with stable long-term revenue expectations. This mechanism design can effectively hedge against uncertainties in a highly competitive environment, incentivizing suppliers to proactively invest in specific assets (such as customized equipment or specialized teams) for deep collaboration, thereby achieving a high degree of alignment between both parties in the supply chain regarding economic interests and quality objectives.

6. Conclusion and Outlook

6.1.Conclusion

This study focuses on supply chain quality governance in the context of digital transformation in the construction industry. By constructing a chain-mediated model of "information technology empowerment—supply chain transparency—quality collaborative behavior—quality performance" and empirically testing it using survey data from 286 construction enterprises and their suppliers, the following core conclusions are drawn.

Firstly, the study confirms that information technology empowerment is a prerequisite driver for enhancing construction supply chain transparency. The breadth of technology application and the depth of data integration significantly break down inter-organizational information barriers, which is consistent with information processing theory's expectation that technological investment expands an organization's information processing capabilities. Secondly, supply chain transparency is validated as a key mechanism for stimulating quality collaborative behavior. High levels of information sharing and visibility significantly promote suppliers' specific investments and joint quality management practices.

A transparent information environment, as an effective governance mechanism, can curb opportunistic behavior and reduce suppliers' concerns about the risks of asset-specific investments. Thirdly, quality collaborative behavior has a significant positive impact on quality performance, indicating that substantive management collaboration and resource input are direct drivers for improving project entity quality and enhancing rectification efficiency.

6.2.Theoretical Contributions

The theoretical contributions of this study are mainly reflected in the deep integration and expansion of information processing theory and transaction cost theory in the context of construction supply chains. First, the study introduces information processing theory into the field of construction supply chain quality management, and empirically tests the transmission path of "information technology—transparency—performance," opening the "black box" of the business value of digital technology. This complements existing literature on the antecedents and consequences of supply chain information sharing, clarifying that technology does not directly create performance, but must be transformed into transparency and collaborative behavior in the management process to be effective. A study on Jordanian firms also highlights that resources do not directly yield performance but must be operationalized through structured management systems as a mediating mechanism to effectively translate into tangible supply chain outcomes (Alkhresheh, 2025). Research in the creative industries similarly finds that digital leadership alone may not directly enhance performance; instead, supply chain integration acts as a pivotal mediator necessary to translate digital strategies into sustainable innovation outcomes (Li et al., 2025). Second, based on transaction cost theory, this study deeply explores the driving mechanism of asset-specific investment. The study finds that supply chain transparency can effectively replace expensive bureaucratic governance and promote specific investments by suppliers in the absence of equity ties.

6.3.Managerial Implications

Based on the research findings, this study provides the following practical implications for construction enterprise managers. First, managers should establish a digital transformation strategy of "promoting collaboration through transparency." Technology investment should not be limited to internal office automation, but should prioritize opening up data interfaces across the supply chain, using information transparency to establish data-driven trust mechanisms, thereby solving the problem of difficult multi-stakeholder collaboration. Second, core enterprises should attach importance to building long-term cooperative relationships to cope with the negative impacts of fierce market competition. General contractors should establish long-term strategic partnerships to provide suppliers with stable cooperation expectations, locking in their high-quality resources and specific technological investments.

6.4.Limitations and Future Research

Despite achieving certain theoretical and practical results, this study still has limitations that need to be improved in future research. First, this study used a questionnaire survey to collect cross-sectional data, which, although revealing significant correlations between variables, was slightly insufficient in the rigor of causal inference. Given the long-cycle nature of construction projects, future research could attempt to collect longitudinal panel data to examine the lagged effects and evolutionary patterns of information technology empowerment on quality performance from a dynamic perspective. Second, although the sample of this study covered multiple provinces along the coast and inland, it was limited to construction enterprises in the Chinese context. Considering the potential impact of cultural differences and institutional environments on supply chain governance, future research could conduct cross-national comparative studies to verify the universality of the mechanisms proposed in this study in different national contexts. Third, this study mainly focused on general information technology empowerment and did not subdivide specific technology types such as artificial intelligence and the

Internet of Things. With the rapid iteration of emerging technologies, future research could further explore the differentiated impact of various types of digital technologies on supply chain governance structures, as well as the balance between exploratory innovation and exploitative innovation in supply chain quality management.

References

Agarwal, R., Chandrasekaran, S., & Sridhar, M. (2016). *Imagining construction's digital future*. McKinsey & Company, 24(06), 1–13.

Alkhresheh, D. A. S. (2025). The Impact of Knowledge Management on Supply Chain Performance Through Performance Management Systems: Evidence from Jordanian Firms. *Journal of Logistics, Informatics and Service Science, 12*(8), 97–113.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*(3), 411–423.

Chidoud, H., Aarab, A., & Amin, L. (2025). Integration of Certified Management Systems and Information Technology for Enhanced Risk Management: Evidence from Morocco's Agri-food Sector. *Journal of Logistics, Informatics and Service Science, 12*(3), 125–140.

Cuypers, I. R., Hennart, J. F., Silverman, B. S., & Ertug, G. (2021). Transaction cost theory: Past progress, current challenges, and suggestions for the future. *Academy of Management Annals, 15*(1), 111–150.

Devaraj, S., Krajewski, L., & Wei, J. C. (2007). Impact of eBusiness technologies on operational performance: The role of production information integration in the supply chain. *Journal of Operations Management, 25*(6), 1199–1216.

Forcael, E., Ferrari, I., Opazo-Vega, A., & Pulido-Arcas, J. A. (2020). Construction 4.0: A literature review. *Sustainability, 12*(22), 9755.

Galbraith, J. (1973). *Designing complex organizations*. Addison-Wesley.

Grigaravičius, D. (2025). Analysis of Digital Technology Application Opportunities in Quality Assurance Processes of the Energy Sector Projects. *Journal of Management Changes in the Digital Era, 2*(1), 170–182.

Grover, V., & Malhotra, M. K. (2003). Transaction cost framework in operations and supply chain management research: Theory and measurement. *Journal of Operations Management, 21*(4), 457–473.

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management, 21*(4), 405–435.

Le, D. T. A., & Dam, S. M. (2025). Big Data Analytics in Food Supply Chain Management: A Systematic Literature Review. *Journal of Logistics, Informatics and Service Science, 12*(7), 124–146.

Li, J., Zhu, F., Lu, F., & Zhang, Y. (2025). How Supply Chain Integration Mediates the Impact of Digital Leadership on Sustainable Innovation: A Case Study of Enlight Media. *Journal of Logistics, Informatics and Service Science, 12*(3), 163–186.

Li, L., Su, Q., & Chen, X. (2011). Ensuring supply chain quality performance through applying the SCOR model. *International Journal of Production Research, 49*(1), 33–57.

Love, P. E., Smith, J., Ackermann, F., Irani, Z., & Teo, P. (2018). The costs of rework: Insights from construction and opportunities for learning. *Production Planning & Control, 29*(13), 1082–1095.

Mojumder, A., & Singh, A. (2021). An exploratory study of the adaptation of green supply chain management in construction industry: The case of Indian construction companies. *Journal of Cleaner Production, 295*, 126400.

Ou, Y., Ismail, M. A. B., & Mohd Sharif, K. I. B. (2025). Supply Chain Collaboration and Green Innovation Performance in Chinese Logistics Services: Policy Heterogeneity and Organizational Capabilities. *Journal of Logistics, Informatics and Service Science, 12*(6), 214–238.

Pan, H., Zou, N., Wang, R., Ma, J., & Liu, D. (2025). Artificial intelligence usage and supply chain resilience: An organizational information processing theory perspective. *Systems, 13*(9), 724.

Prajogo, D., & Olhager, J. (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics, 135*(1), 514–522.

Roeck, D., Sternberg, H., & Hofmann, E. (2020). Distributed ledger technology in supply chains: A transaction cost perspective. *International Journal of Production Research, 58*(7), 2124–2141.

Simanjuntak, A., Goh, T. S., Sagala, F., Sitangggang, D. P., & Nadeak, H. I. (2025). Digital Informatics Integration in Manufacturing Supply Chains: Enhancing Environmental Service Quality and Logistics Efficiency Through Smart Accounting Systems. *Journal of Logistics, Informatics and Service Science, 12*(6), 59–76.

Stroumpoulis, A., & Kopanaki, E. (2022). Theoretical perspectives on sustainable supply chain management and digital transformation: A literature review and a conceptual framework. *Sustainability, 14*(8), 4862.

Syafrianita, Purnomo, A., Amran, K. M., Chaidar, D. F. R., & Pakpahan, H. M. (2025). Green Technology and Transportation in Supply Chain Management: The Mediating Role of Agility on Performance in Indonesia's Courier Industry. *Journal of Logistics, Informatics and Service Science, 12*(4), 338–359.

Wang, W., Khatibi, A., & Tham, J. (2025). A Scientometric Review of Quality Management, Employee Satisfaction, and Organizational Effectiveness in the Construction Industry: A Visualization with CiteSpace. *Journal of Logistics, Informatics and Service Science, 12*(6), 77–96.

Wickens, C. D., & Carswell, C. M. (2021). Information processing. In *Handbook of human factors and ergonomics* (pp. 114–158). Wiley.

Williamson, O. E. (1975). *Markets and hierarchies: Analysis and antitrust implications: A study in the economics of internal organization*. Free Press.

Wu, J., & Yu, J. (2023). Blockchain's impact on platform supply chains: Transaction cost and information transparency perspectives. *International Journal of Production Research, 61*(11), 3703–3716.

Wu, Y., Li, H., Luo, R., & Yu, Y. (2024). How digital transformation helps enterprises achieve high-quality development? Empirical evidence from Chinese listed companies. *European Journal of Innovation Management, 27*(8), 2753–2779.

Yeung, K., Lee, P. K., Yeung, A. C., & Cheng, T. C. E. (2013). Supplier partnership and cost performance: The moderating roles of specific investments and environmental uncertainty. *International Journal of Production Economics, 144*(2), 546–559.

Yuan, Y., & Li, W. (2022). The effects of supply chain risk information processing capability and supply chain finance on supply chain resilience: A moderated and mediated model. *Journal of Enterprise Information Management, 35*(6), 1592–1612.

Zdravković, M., Panetto, H., & Weichhart, G. (2022). AI-enabled enterprise information systems for manufacturing. *Enterprise Information Systems, 16*(4), 668–720.

Zeng, J., Phan, C. A., & Matsui, Y. (2015). The impact of hard and soft quality management on quality and innovation performance: An empirical study. *International Journal of Production Economics, 162*, 216–226.

Zhou, H., & Benton, W. C., Jr. (2007). Supply chain practice and information sharing. *Journal of Operations Management, 25*(6), 1348–1365.