Enhancing Supply Chain Operational Performance through Management Practices and Capabilities: The Mediating Role of Technology Adoption

Yunan Zhou[1], Prof. Madya Dr. Zulkifli Mohamed Udin[1*], Md. Abdul Kafi[1]

[1]College of Business, Universiti Utara Malaysia, Kedah, Malaysia

Author Emails:

Yunan Zhou: yunanuum23@gmail.com

Prof. Madya Dr. Zulkifli Mohamed Udin: zulkifli@uum.edu.my

Md. Abdul Kafi: md.abdul.kafi@uum.edu.my

***Corresponding Author:** Prof. Madya Dr. Zulkifli Mohamed Udin |

Email: zulkifli@uum.edu.my

Abstract

The increasing operational complexity of cold chain logistics and the rapid digital transformation within China's logistics industry have intensified the need for cold storage firms to improve supply chain operational performance (SCOP). Despite continuous investments in digital technologies, many cold storage organizations continue to encounter operational inefficiencies associated with fragmented managerial coordination, inconsistent technology implementation, and varying organizational capabilities, thereby creating an important research gap regarding the mediating role of Supply Chain Technology Adoption (SCTA) within operational supply chain environments. Grounded in the Technology-Organization-Environment (TOE) framework, this study examined the relationships among Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), SCTA, and SCOP among cold storage firms in Beijing, China. A quantitative cross-sectional research design was adopted, and data were collected from 300 supply chain managers and logistics personnel using purposive sampling. The collected data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) through SmartPLS software. The measurement model assessment demonstrated strong indicator reliability, convergent validity, and discriminant validity, with factor loading values ranging from 0.908 to 0.973, AVE values ranging from 0.872 to 0.914, and HTMT values below 0.90. The structural model findings revealed that SCMP significantly influenced SCTA (H1: $\beta = -0.541$, $t = 10.824$, $p = 0.000$) and SCOP (H3: $\beta = -0.238$, $t = 4.220$, $p = 0.000$). Additionally, SCC significantly influenced SCOP (H4: $\beta = 0.707$, $t = 17.743$, $p = 0.000$), while SCTA significantly influenced SCOP (H5: $\beta = -0.380$, $t = 6.726$, $p = 0.000$). The mediation analysis further demonstrated that SCTA significantly mediated the relationship between SCMP and SCOP through complementary partial mediation (H6: $\beta = 0.205$, $t = 5.108$, $p = 0.000$). These findings indicate that managerial coordination and supply chain integration significantly influence operational performance through technology-enabled operational systems, while organizational capabilities independently strengthen operational effectiveness within cold storage operations. The study contributes theoretically by extending the TOE framework within the cold storage logistics context and practically by providing strategic implications for improving digital transformation readiness, operational coordination, and technological integration within China's cold chain logistics industry.

Keywords: Supply Chain Operational Performance, Supply Chain Management Practices, Supply Chain Capabilities, Supply Chain Technology Adoption, Cold Storage Industry, TOE Framework, PLS-SEM, Beijing China

1.0 Introduction

The rapid expansion of China's logistics sector and the increasing demand for cold chain transportation have intensified the strategic importance of supply chain operational performance within the cold storage industry. As one of the world's largest food production and consumption markets, China relies heavily on efficient cold chain logistics systems to ensure food safety, pharmaceutical preservation, inventory stability, and operational sustainability across domestic and international markets. In recent years, the Chinese government has aggressively promoted digital transformation initiatives within the logistics sector through policies such as the "14th Five-Year Plan for Cold Chain Logistics Development," which emphasizes smart logistics systems, digital infrastructure integration, and technological modernization within cold storage operations. Despite these national initiatives, many cold storage firms continue to experience operational inefficiencies associated with fragmented coordination systems, inconsistent technology implementation, and weak organizational integration. Consequently, improving Supply Chain Operational Performance (SCOP) through effective managerial practices, organizational capabilities, and technological adoption has become increasingly important within China's cold storage industry. Within this context, the present study investigates the influence of Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), and Supply Chain Technology Adoption (SCTA) on operational performance among cold storage firms in Beijing, China, grounded in the Technology-Organization-Environment (TOE) framework.

China's cold storage industry currently faces multiple operational and technological challenges that directly affect supply chain efficiency and service quality. Although the country has significantly invested in logistics modernization and digital transformation, operational disruptions within cold chain systems remain prevalent due to inadequate coordination among supply chain partners, inconsistent adoption of digital technologies, and weak integration between operational units. Previous studies have highlighted that many logistics firms in China continue to struggle with real-time inventory visibility, information sharing inefficiencies, temperature monitoring inconsistencies, and limited technological interoperability across supply chain networks (Pamisetty, 2023). Furthermore, rapid urbanization, increasing e-commerce demand, and rising consumer expectations for fresh food and pharmaceutical safety have intensified operational pressures on cold storage organizations. Within Beijing specifically, the concentration of logistics hubs, distribution centers, and cold storage facilities has created highly competitive operational environments requiring firms to improve responsiveness, agility, and operational coordination to maintain sustainable performance outcomes (Pajić et al., 2024). However, despite increasing technological investments, many organizations continue to face difficulties in integrating managerial practices and organizational capabilities with digital operational systems, thereby limiting the effectiveness of technological transformation initiatives within the cold chain sector.

The operational problems within China's cold storage industry are further intensified by the complexity of supply chain coordination and the uneven adoption of advanced technological systems. Cold storage operations require continuous monitoring, temperature-sensitive transportation, real-time inventory management, and coordinated supplier relationships to maintain operational stability and product quality (Sanni, 2024). Nevertheless, many organizations continue to operate with fragmented managerial systems, limited supply chain integration, and inconsistent technological readiness, which negatively affect operational reliability and responsiveness. Existing literature has demonstrated that weak Supply Chain Management Practices (SCMP), including ineffective information sharing and insufficient operational coordination, frequently contribute to operational inefficiencies and performance instability within logistics-intensive industries (Aslam et al., 2026). Additionally, inadequate organizational capabilities such as weak strategic sourcing capability, limited collaborative trust, and ineffective organizational culture further constrain firms' ability to achieve operational

excellence. While technologies such as Internet of Things (IoT), Radio Frequency Identification (RFID), cloud-based inventory systems, and automation technologies have increasingly been introduced within cold storage operations, the successful implementation of these technologies remains highly dependent on organizational readiness and managerial coordination. Consequently, technological investments alone may not sufficiently improve operational performance unless supported by effective managerial practices and organizational capabilities (Muhajji et al., 2024).

Despite the growing body of literature on supply chain management and technological adoption, several important research gaps remain insufficiently addressed. First, previous studies have primarily focused on manufacturing industries, general logistics sectors, or broader digital transformation contexts, while limited empirical attention has been given specifically to the cold storage industry in China (C.-B. Kim et al., 2025). Second, existing studies have often examined the direct relationships between managerial practices, organizational capabilities, and operational performance without adequately investigating the mediating role of Supply Chain Technology Adoption (SCTA) within these relationships (Alam et al., 2023). Furthermore, prior studies have produced inconsistent findings regarding the effectiveness of technology adoption in strengthening operational performance outcomes, particularly within operationally intensive industries such as cold storage logistics (Tariq & Ali, 2025). In addition, limited studies have specifically focused on supply chain managers and logistics personnel operating within Beijing's cold storage industry, thereby creating both population and geographical gaps in the literature (B. Zhang & Mohammad, 2024). Since Beijing represents one of China's most strategically important logistics and distribution hubs, examining the operational challenges faced by cold storage firms within this geographical context is critically important for understanding the effectiveness of managerial coordination, organizational capabilities, and technological integration in improving operational performance. Therefore, the primary objective of this study is to examine the relationships among SCMP, SCC, SCTA, and SCOP, while specifically investigating the mediating role of SCTA within cold storage firms in Beijing, China.

This study contributes both theoretically and practically to the existing supply chain and logistics literature. Theoretically, the study extends the Technology-Organization-Environment (TOE) framework by examining the differentiated mediating role of Supply Chain Technology Adoption within the relationships between managerial practices, organizational capabilities, and operational performance in the cold storage context. Methodologically, the study contributes empirical evidence through the application of Partial Least Squares Structural Equation Modeling (PLS-SEM) among supply chain managers and logistics personnel within Beijing's cold storage industry. Practically, the findings provide strategic implications for logistics firms and policymakers regarding the importance of managerial coordination, organizational capability development, and technological readiness in improving operational efficiency and digital transformation effectiveness. The remainder of this paper is organized as follows. The next section reviews the underpinning theory and relevant literature related to supply chain operational performance, managerial practices, organizational capabilities, and technology adoption. Subsequently, the methodology section explains the research design, sampling procedures, and analytical techniques utilized in the study. The following sections present the empirical findings, discussion, and implications of the study before concluding with limitations and recommendations for future research.

1.1 Research Problem Statement

The rapid growth of China's cold chain logistics industry has significantly increased the operational importance of cold storage firms in ensuring food safety, pharmaceutical preservation, inventory stability, and efficient distribution systems across domestic and international markets. As one of the world's largest logistics economies, China has continuously emphasized digital transformation and smart logistics development through national initiatives such as the "14th Five-Year Plan for Cold Chain

Logistics Development," which encourages technological modernization, supply chain integration, and intelligent logistics systems within the cold chain sector. Despite these initiatives, many cold storage firms continue to experience operational inefficiencies associated with fragmented supply chain coordination, inconsistent technology implementation, weak organizational integration, and limited operational responsiveness (Hasmawati, 2024). These operational challenges have created growing concerns regarding the ability of cold storage organizations to maintain sustainable operational performance within increasingly competitive and technology-intensive logistics environments. Consequently, improving Supply Chain Operational Performance (SCOP) through effective managerial practices, organizational capabilities, and technological adoption has become a critical strategic concern for China's cold storage industry.

Existing studies have consistently highlighted that ineffective Supply Chain Management Practices (SCMP), including weak information sharing, insufficient supply chain integration, and poor operational coordination, negatively affect organizational responsiveness, agility, and operational efficiency within logistics-intensive industries (Bekele et al., 2025). Furthermore, inadequate Supply Chain Capabilities (SCC), such as weak organizational culture capability, ineffective strategic sourcing, and limited trust-based collaboration, frequently constrain firms' ability to achieve operational excellence and supply chain resilience (Gupta, 2024). Although technological systems such as Internet of Things (IoT), Radio Frequency Identification (RFID), cloud-based inventory systems, and automation technologies have increasingly been adopted within cold chain operations, many organizations continue to struggle with technological integration and operational alignment. Previous research has also reported that technological adoption alone does not necessarily improve operational performance unless supported by effective managerial coordination and organizational readiness (Chatha et al., 2023). Consequently, operational inefficiencies within cold storage firms remain prevalent despite increasing technological investments and digital transformation initiatives.

Despite the growing body of literature on supply chain management and technology adoption, several important research gaps remain insufficiently addressed. First, previous studies have predominantly focused on manufacturing industries, e-commerce logistics, or general supply chain systems, while limited empirical attention has been devoted specifically to the cold storage industry in China (Wang et al., 2024). The operational complexity of cold storage logistics differs substantially from other logistics sectors because temperature-sensitive operations require continuous monitoring, coordinated transportation systems, and real-time operational visibility. Therefore, findings derived from other industries may not be fully generalizable to cold chain environments. Second, prior studies have largely examined the direct relationships between supply chain management practices, organizational capabilities, technology adoption, and operational performance independently, while limited research has investigated the mediating role of Supply Chain Technology Adoption (SCTA) within these relationships. In particular, inconsistent findings regarding whether technological adoption strengthens or weakens operational performance outcomes have created theoretical ambiguity within the existing literature (Raj & Jeyaraj, 2023). Furthermore, limited studies have simultaneously examined SCMP, SCC, SCTA, and SCOP within a unified framework grounded in the Technology-Organization-Environment (TOE) theory, particularly within operationally intensive logistics sectors.

In addition to the theoretical gap, significant population and geographical gaps also exist within the current literature. Most previous studies have focused on manufacturing firms, multinational corporations, or broader logistics organizations located in developed economies, while limited empirical evidence has specifically examined supply chain managers and logistics personnel operating within Beijing's cold storage industry. Beijing represents one of China's most strategically important logistics and distribution hubs, characterized by high logistics intensity, increasing digital transformation initiatives, and growing demand for cold chain operational efficiency (F. Li et al., 2022).

However, the operational challenges faced by cold storage firms within this geographical context remain underexplored. Therefore, the present study addresses these gaps by examining the influence of Supply Chain Management Practices and Supply Chain Capabilities on Supply Chain Operational Performance through the mediating role of Supply Chain Technology Adoption among cold storage firms in Beijing, China.

This study contributes toward solving the identified research problems by providing empirical evidence regarding the direct and indirect relationships among managerial practices, organizational capabilities, technological adoption, and operational performance within the cold storage industry. Specifically, the study extends the Technology-Organization-Environment (TOE) framework by examining how technological adoption functions as a mediating mechanism linking organizational and managerial factors to operational performance outcomes (Amin et al., 2024). The findings are expected to assist cold storage firms, logistics practitioners, and policymakers in understanding how managerial coordination, organizational capabilities, and technological readiness collectively influence operational efficiency, responsiveness, and supply chain integration. Furthermore, the study provides practical insights for improving digital transformation strategies, operational coordination systems, and technology-enabled logistics management within China's rapidly evolving cold chain logistics sector.

2.0 Literature Review

The present study is grounded in the Technology-Organization-Environment (TOE) framework, which explains that organizational technology adoption is influenced by technological readiness, organizational capability, and environmental conditions that collectively determine organizational performance outcomes. The TOE framework is particularly suitable for this study because the research investigates how organizational factors, namely Supply Chain Management Practices (SCMP) and Supply Chain Capabilities (SCC), influence Supply Chain Technology Adoption (SCTA), which subsequently enhances Supply Chain Operational Performance (SCOP) among cold storage firms in Beijing, China. Within the Chinese context, the cold storage industry has become increasingly important due to the rapid expansion of e-commerce logistics, pharmaceutical distribution, frozen food supply chains, and smart logistics systems (Sun et al., 2023). The Chinese government has intensified digital transformation initiatives under the "14th Five-Year Plan" and the "Digital China" strategy, which emphasize intelligent logistics infrastructure, cold chain modernization, and technology-driven supply chain integration. These initiatives encourage cold storage firms to adopt technologies such as Internet of Things (IoT), RFID systems, automation technologies, cloud computing, and intelligent warehousing systems to improve operational reliability and logistics responsiveness. However, despite governmental support, many cold storage firms continue to experience operational inefficiencies associated with fragmented coordination, inadequate technological readiness, weak organizational culture capability, and limited strategic integration among supply chain personnel and managers. From the TOE perspective, organizations possessing stronger managerial practices and organizational capabilities are more likely to adopt supply chain technologies effectively and achieve superior operational performance outcomes within highly competitive logistics environments (Bui & Vu Tran, 2026). Therefore, the TOE framework provides a comprehensive theoretical explanation linking organizational practices, technological adoption, and operational performance within the cold storage industry in Beijing, China.

Supply Chain Operational Performance (SCOP), which represents the dependent variable of this study, refers to the operational effectiveness of firms in terms of responsiveness, agility, reliability, flexibility, and cost efficiency within supply chain operations. Recent literature has increasingly emphasized that operational performance within logistics-intensive industries is highly dependent on organizations' ability to integrate managerial practices, organizational capabilities, and technological systems effectively (Coşkun & Erturgut, 2025). Supply Chain Management Practices (SCMP), including

information sharing, supply chain coordination, and operational integration, have been widely recognized as strategic mechanisms that improve operational efficiency and organizational responsiveness. Prior studies demonstrated that firms implementing collaborative supply chain practices tend to achieve better operational visibility and coordination efficiency, which subsequently enhance operational performance outcomes (Khan et al., 2024). Similarly, Supply Chain Capabilities (SCC), particularly organizational culture capability, trust development, and strategic sourcing capability, positively influence operational adaptability (Sabiu et al., 2025) and supply chain resilience because these capabilities strengthen firms' ability to respond to environmental uncertainties and operational disruptions (Pu et al., 2023).

Nevertheless, recent studies have argued that the direct relationship between managerial practices and operational performance is increasingly dependent upon technological integration within supply chain systems. This suggests that Supply Chain Technology Adoption (SCTA) functions as an important mediating mechanism that enables organizations to transform managerial practices and organizational capabilities into operational performance improvements. Existing studies revealed that firms adopting advanced supply chain technologies achieve superior logistics responsiveness, inventory accuracy, operational transparency, and supply chain agility compared to firms relying on conventional operational systems (Holloway, 2025). Furthermore, prior literature indicated that organizations possessing strong supply chain management practices are more capable of adopting digital technologies because effective coordination, information sharing, and collaborative integration improve organizational readiness toward digital transformation initiatives (Le et al., 2024). Likewise, firms with stronger organizational capabilities demonstrate greater technological adaptability and innovation acceptance, which positively influence supply chain technology adoption processes (Le et al., 2024). However, empirical findings remain inconsistent because some firms fail to achieve significant operational improvements despite technological investments due to weak managerial support and inadequate organizational capability structures. This limitation is particularly critical within cold storage industries where operational precision, temperature-sensitive logistics, real-time monitoring systems, and inventory visibility are essential operational requirements.

Consequently, the present study proposes that Supply Chain Management Practices and Supply Chain Capabilities significantly influence Supply Chain Technology Adoption and Supply Chain Operational Performance among cold storage firms in Beijing, China. In addition, Supply Chain Technology Adoption is proposed to significantly influence Supply Chain Operational Performance and mediate the relationships between the independent variables and operational performance outcomes. Accordingly, the present study proposes seven hypotheses: H1 proposes that Supply Chain Management Practices significantly influence Supply Chain Technology Adoption; H2 proposes that Supply Chain Capabilities significantly influence Supply Chain Technology Adoption; H3 proposes that Supply Chain Management Practices significantly influence Supply Chain Operational Performance; H4 proposes that Supply Chain Capabilities significantly influence Supply Chain Operational Performance; H5 proposes that Supply Chain Technology Adoption significantly influences Supply Chain Operational Performance; H6 proposes that Supply Chain Technology Adoption mediates the relationship between Supply Chain Management Practices and Supply Chain Operational Performance; and H7 proposes that Supply Chain Technology Adoption mediates the relationship between Supply Chain Capabilities and Supply Chain Operational Performance among cold storage firms in Beijing, China.

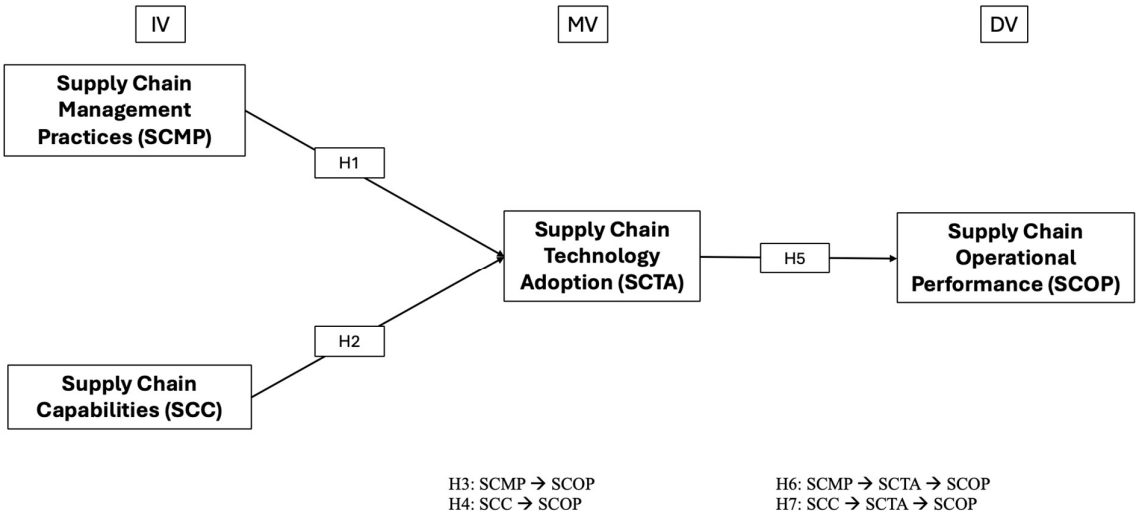

Figure 1: Proposed Research Framework on the Relationship between Supply Chain Management Practices, Supply Chain Capabilities, Supply Chain Technology Adoption, and Supply Chain Operational Performance.

Figure 1 illustrates the proposed conceptual framework of the study, which examines the direct and indirect relationships among Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), Supply Chain Technology Adoption (SCTA), and Supply Chain Operational Performance (SCOP) within the cold storage industry in Beijing, China. The framework proposes that SCMP and SCC function as independent variables influencing both SCTA and SCOP, while SCTA acts as the mediating variable linking organizational and managerial factors to operational performance outcomes. Specifically, H1 and H2 represent the relationships between SCMP and SCC toward SCTA, whereas H3 and H4 examine the direct effects of SCMP and SCC on SCOP. Additionally, H5 represents the direct relationship between SCTA and SCOP. The framework further incorporates mediation relationships through H6 and H7 to assess whether SCTA mediates the relationships between the independent variables and operational performance. Grounded in the Technology-Organization-Environment (TOE) framework, the conceptual model emphasizes the strategic importance of managerial coordination, organizational capabilities, and technological adoption in improving operational responsiveness, integration, efficiency, and reliability within cold storage supply chain operations.

3.0 Methodology

3.1 Research Design

This study employed a quantitative research design using a deductive research approach to examine the relationships among Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), Supply Chain Technology Adoption (SCTA), and Supply Chain Operational Performance (SCOP) within the cold storage industry in Beijing, China. A cross-sectional survey method was utilized because the study aimed to test the proposed hypotheses and examine causal relationships among the variables at a single point in time. The quantitative approach was considered appropriate due to its suitability for hypothesis testing, statistical generalization, and predictive analysis within organizational research settings.

3.2 Population and Sampling

The target population of this study consisted of supply chain managers, logistics personnel, and operational managers working in cold storage firms located in Beijing, China. These respondents were selected because they possess relevant knowledge and practical experience regarding supply chain operations, technological implementation, and organizational performance within the cold storage industry. The study adopted purposive sampling as the primary sampling technique because it specifically targeted respondents with expertise relevant to the research objectives. Purposive sampling is appropriate for industry-specific studies where knowledgeable respondents are required to provide reliable organizational information. A total of 438 questionnaires were distributed, of which 350 questionnaires were successfully returned, representing a response rate of 80%. After data screening and cleaning procedures, 300 valid responses were retained for final analysis. The sample size was considered adequate for Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis based on contemporary methodological recommendations (Hair & Alamer, 2022).

3.3 Data Collection Procedure

Data collection was conducted using a structured self-administered questionnaire distributed to selected respondents from cold storage firms in Beijing, China. Prior to the main data collection process, the questionnaire was reviewed to ensure clarity, readability, and contextual suitability for the cold storage industry. The questionnaires were distributed through both physical and online platforms to increase accessibility and response rates. Respondents were informed regarding the purpose of the study and the confidentiality of their responses before participation.

3.4 Research Instrument

The research instrument consisted of two sections: demographic information and measurement items for the study variables. All measurement items were assessed using a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Supply Chain Management Practices (SCMP) were measured using items adapted from Hani (2022), focusing on information sharing, operational coordination, and supply chain integration. Example items included effective information sharing with supply chain partners and coordination efficiency with suppliers and logistics providers. Supply Chain Capabilities (SCC) were measured using items adapted from Luqman et al. (2023), emphasizing organizational culture capability, strategic sourcing capability, and trust-based collaboration among supply chain stakeholders. Example items included organizational support for collaborative supply chain culture and strategic trust relationships with supply chain partners. Supply Chain Technology Adoption (SCTA) was measured using items adapted from Lyu et al. (2024) focusing on the adoption and utilization of IoT systems, RFID technologies, automation tools, cloud systems, and real-time monitoring technologies within supply chain operations. Meanwhile, Supply Chain Operational Performance (SCOP) was measured using items adapted from Nguyen (2024) focusing on operational responsiveness, reliability, agility, flexibility, and cost efficiency. Example items included operational responsiveness to customer demand changes and effectiveness in managing operational costs. The measurement items were slightly modified to suit the operational context of the cold storage industry in Beijing, China.

3.5 Data Analysis Technique

The collected data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) through SmartPLS software. PLS-SEM was selected because it is suitable for predictive-oriented research models involving mediation analysis and multiple latent constructs. The analysis process consisted of two stages, namely measurement model assessment and structural model assessment. The measurement model evaluation examined internal consistency reliability, convergent validity, and

discriminant validity using Cronbach's alpha, composite reliability, average variance extracted (AVE), and heterotrait-monotrait ratio (HTMT). Subsequently, the structural model assessment evaluated path coefficients, coefficient of determination (R^2), predictive relevance (Q^2), and mediation effects using bootstrapping procedures with 5,000 resamples to test the significance of the proposed hypotheses (Hair & Alamer, 2022).

3.6 Ethical Considerations

Ethical considerations were strictly observed throughout the research process to ensure responsible and transparent research conduct. Respondents were informed about the objectives of the study, the voluntary nature of participation, and their right to withdraw from the study at any stage without penalty. Informed consent was obtained prior to questionnaire administration. In addition, respondents' identities and organizational information were kept strictly confidential and used solely for academic purposes. The study ensured anonymity and data protection throughout the data collection and analysis process in accordance with institutional ethical research guidelines.

4.0 Results and Discussion

4.1 Respondents' Demographic Profile

A total of 438 questionnaires were distributed to supply chain managers, logistics personnel, and operational managers from cold storage firms in Beijing, China. Out of the distributed questionnaires, 350 were successfully returned, representing a response rate of 80%. Following data screening and cleaning procedures, 300 valid responses were retained for final analysis. The response rate was considered satisfactory and exceeded the minimum acceptable threshold for organizational survey-based studies, indicating adequate representativeness of the targeted population (Hair & Alamer, 2022). The respondents consisted primarily of managerial and operational personnel directly involved in supply chain activities, technological implementation, and logistics operations within the cold storage sector. The demographic findings demonstrated that the respondents possessed sufficient industry experience and operational knowledge relevant to the objectives of this study, thereby strengthening the reliability and credibility of the collected data.

Table 1: Demographic Profile of Supply Chain Managers and Logistics Personnel in Cold Storage Firms in Beijing, China

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	186	62.0
	Female	114	38.0
Age Group	21–30 years	58	19.3
	31–40 years	124	41.3
	41–50 years	82	27.3
	Above 50 years	36	12.0
Educational Level	Diploma	52	17.3
	Bachelor's Degree	171	57.0
	Master's Degree	61	20.3
	Doctorate Degree	16	5.4
Position in Organization	Supply Chain Manager	96	32.0
	Logistics Manager	74	24.7
	Operations Manager	58	19.3
	Supply Chain Personnel	72	24.0
Working Experience	Less than 5 years	47	15.7
	5–10 years	119	39.7

	11–15 years	86	28.6
	More than 15 years	48	16.0
Firm Size	Small Enterprise	62	20.7
	Medium Enterprise	143	47.6
	Large Enterprise	95	31.7
Technology Adoption Level	Low	38	12.7
	Moderate	156	52.0
	High	106	35.3

The demographic findings presented in Table 4.1 indicate that the majority of respondents were male (62.0%) and predominantly within the age group of 31–40 years (41.3%), suggesting that most respondents were within the active managerial and operational workforce of the cold storage industry. Most respondents possessed a Bachelor's degree (57.0%) and held managerial positions related to supply chain and logistics operations, indicating that the respondents possessed relevant educational background and professional expertise required for the study. Additionally, a large proportion of respondents had between 5 to 10 years of working experience (39.7%), demonstrating substantial operational exposure within the industry. The findings also revealed that medium-sized enterprises constituted the largest proportion of participating firms (47.6%), while most organizations demonstrated moderate levels of supply chain technology adoption (52.0%). Overall, the demographic profile suggests that the collected data were obtained from experienced and knowledgeable respondents directly involved in supply chain operations and technological implementation within Beijing's cold storage industry.

4.2 Measurement Model Assessment

4.2.1 Indicator Reliability

The measurement model assessment was conducted to evaluate the reliability and validity of the constructs before proceeding to the structural model analysis using Partial Least Squares Structural Equation Modeling (PLS-SEM). Indicator reliability was first assessed by examining the factor loading values of all measurement items. According to Hair & Alamer, (2022), factor loading values exceeding the threshold value of 0.70 indicate satisfactory indicator reliability and confirm that the indicators adequately represent their respective latent constructs.

The findings presented in Table 1 demonstrated that all measurement items achieved exceptionally high loading values ranging between 0.908 and 0.973, thereby substantially exceeding the recommended threshold value. Specifically, the indicators for Supply Chain Capabilities (SCC) recorded loading values of 0.957, 0.946, 0.958, 0.973, 0.951, and 0.953. Similarly, the indicators for Supply Chain Management Practices (SCMP) recorded loading values of 0.950, 0.925, 0.947, 0.944, 0.944, and 0.962. Supply Chain Operational Performance (SCOP) demonstrated loading values of 0.942, 0.908, 0.942, 0.934, 0.934, and 0.943, while Supply Chain Technology Adoption (SCTA) recorded loading values of 0.933, 0.950, 0.942, 0.949, 0.933, and 0.934. These findings indicate that all indicators possessed strong explanatory power and adequately represented their respective constructs within the proposed research framework.

4.2.2 R-square Adjusted Assessment

The coefficient of determination (R-square) was assessed to evaluate the explanatory power of the endogenous constructs within the structural model. According to Hair & Alamer (2022) higher R-square values indicate stronger predictive and explanatory capability of the model.

As presented in Table 2, Supply Chain Operational Performance (SCOP) recorded an R-square value of 0.582 and an adjusted R-square value of 0.979. This finding indicates that approximately 58.2% of the variance in SCOP was explained by the predictor variables included in the model, namely Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), and Supply Chain Technology Adoption (SCTA). Similarly, Supply Chain Technology Adoption (SCTA) recorded an R-square value of 0.289 and an adjusted R-square value of 0.884, indicating that approximately 28.9% of the variance in SCTA was explained by the independent variables. Overall, the findings demonstrate that the proposed research framework possessed satisfactory explanatory power and predictive capability.

Table 2 R-square Adjusted Value

Constructs	R-square	R-square Adjusted
SCOP	0.582	0.979
SCTA	0.289	0.884

4.2.3 F-square Assessment

The effect size (f-square) assessment was conducted to evaluate the individual contribution of each exogenous construct toward the endogenous constructs within the structural model. According to Hair & Alamer (2022) f-square values of 0.02, 0.15, and 0.35 indicate small, medium, and large effect sizes, respectively.

The findings presented in Table 3 demonstrated that the relationship between SCC and SCOP recorded an f-square value of 1.048, indicating a very large effect size and suggesting that Supply Chain Capabilities exerted a substantial influence on Supply Chain Operational Performance. In contrast, the relationship between SCC and SCTA recorded an f-square value of 0.000, indicating no meaningful effect size. Furthermore, the relationship between SCMP and SCOP recorded an f-square value of 0.087, indicating a small effect size, whereas the relationship between SCMP and SCTA recorded an f-square value of 0.359, demonstrating a large effect size. Lastly, the relationship between SCTA and SCOP recorded an f-square value of 0.246, indicating a medium effect size. These findings suggest that Supply Chain Management Practices strongly influenced technology adoption, while Supply Chain Capabilities exerted a dominant influence on operational performance within the cold storage industry.

Table 3 F-square Value

Relationship	f-square
SCC → SCOP	1.048
SCC → SCTA	0.000
SCMP → SCOP	0.087
SCMP → SCTA	0.359
SCTA → SCOP	0.246

4.2.4 Construct Reliability and Convergent Validity

Construct reliability and convergent validity were assessed using Cronbach's alpha, Composite Reliability (rho_a), Composite Reliability (rho_c), and Average Variance Extracted (AVE). The findings presented in Table 4 demonstrated that all constructs exceeded the recommended threshold values for reliability and validity assessment.

Specifically, Supply Chain Capabilities (SCC) recorded Cronbach's alpha, rho_a, and rho_c values of 0.981, 0.982, and 0.985, respectively, while achieving an AVE value of 0.914. Similarly, Supply Chain Management Practices (SCMP) recorded values of 0.976, 0.977, and 0.981, with an AVE value of 0.894. Supply Chain Operational Performance (SCOP) recorded reliability values of 0.971, 0.971, and 0.976, alongside an AVE value of 0.872. Meanwhile, Supply Chain Technology Adoption (SCTA) demonstrated values of 0.974, 0.974, and 0.979, with an AVE value of 0.884. Since all Cronbach's alpha and composite reliability values exceeded 0.70 and all AVE values exceeded 0.50, the findings confirm excellent internal consistency reliability and satisfactory convergent validity of the constructs within the proposed model.

Table 4 Construct Reliability and Validity Value

Constructs	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
SCC	0.981	0.982	0.985	0.914
SCMP	0.976	0.977	0.981	0.894
SCOP	0.971	0.971	0.976	0.872
SCTA	0.974	0.974	0.979	0.884

4.3 Discriminant Validity Assessment and Heterotrait-Monotrait Ratio of Correlations (HTMT)

Discriminant validity assessment was conducted using the Heterotrait-Monotrait Ratio of Correlations (HTMT) to determine whether the constructs were empirically distinct from one another. Henseler et al. (2021) recommended that HTMT values should remain below the threshold value of 0.90 to confirm satisfactory discriminant validity.

The findings presented in Table 5 demonstrated that all HTMT values remained below the recommended threshold value. Specifically, the HTMT value between SCC and SCMP was 0.362, while the relationship between SCC and SCOP recorded a value of 0.708. Similarly, the HTMT values between SCC and SCTA, SCMP and SCOP, and SCMP and SCTA were 0.185, 0.222, and 0.550, respectively. The HTMT value between SCOP and SCTA recorded 0.390. Since all HTMT values remained substantially below 0.90, the findings confirm satisfactory discriminant validity and indicate that the constructs were empirically distinct without multicollinearity concerns.

Table 5 Discriminant Validity Assessment and Heterotrait-Monotrait Ratio of Correlations (HTMT)

Constructs	SCC	SCMP	SCOP	SCTA
SCC	—			
SCMP	0.362	—		
SCOP	0.708	0.222	—	
SCTA	0.185	0.550	0.390	—

Overall, the findings from the measurement model assessment confirmed that the proposed research framework demonstrated strong indicator reliability, satisfactory explanatory power, acceptable effect sizes, excellent construct reliability, strong convergent validity, and satisfactory discriminant validity. Therefore, the model was considered statistically robust and theoretically adequate for subsequent structural model analysis using PLS-SEM.

4.6 Structural Model Assessment

Structural model assessment was conducted using the bootstrapping procedure in SmartPLS with 5,000 resamples to evaluate the significance of the hypothesized direct relationships among the constructs. The structural model assessment involves examining path coefficients, t-values, standard deviation values, and p-values to determine the significance and strength of the hypothesized relationships within the proposed research framework.

The findings presented in Table 6 demonstrated that Supply Chain Management Practices (SCMP) had a significant negative relationship with Supply Chain Technology Adoption (SCTA), thereby supporting H1. Specifically, the path coefficient recorded a value of -0.541, with a t-value of 10.824 and a p-value of 0.000, indicating a statistically significant relationship at the 0.05 significance level. The finding suggests that variations in supply chain management practices significantly influenced technology adoption within cold storage firms in Beijing, China. Although the relationship was statistically significant, the negative coefficient indicates that ineffective or less adaptive managerial practices may reduce the effectiveness of technology adoption within organizational operations. This finding highlights the operational complexity within cold storage firms, where managerial coordination and operational integration may not always align positively with digital transformation initiatives (Fatorachian & Pawar, 2025).

In contrast, H2, which proposed a relationship between Supply Chain Capabilities (SCC) and Supply Chain Technology Adoption (SCTA), was not supported. The path coefficient recorded a value of 0.010, with a t-value of 0.210 and a p-value of 0.833, indicating an insignificant relationship between the constructs. This finding suggests that organizational capabilities such as organizational culture capability, strategic sourcing capability, and trust-based collaboration did not significantly influence technology adoption within the sampled cold storage firms (Romeo et al., 2025). The result may indicate that technology adoption within Beijing's cold storage industry is more strongly driven by operational requirements and managerial systems rather than broader organizational capabilities (Li et al., 2025).

The findings further demonstrated that H3, which examined the relationship between Supply Chain Management Practices (SCMP) and Supply Chain Operational Performance (SCOP), was supported. The path coefficient recorded a value of -0.238, with a t-value of 4.220 and a p-value of 0.000, indicating a statistically significant relationship. Similar to H1, the negative coefficient suggests that weaknesses in managerial coordination and operational integration may negatively influence operational performance outcomes within the cold storage industry. This result reflects the operational challenges associated with fragmented coordination systems and insufficient integration among supply chain activities (Anwar et al., 2025).

Additionally, H4 revealed that Supply Chain Capabilities (SCC) had a significant positive relationship with Supply Chain Operational Performance (SCOP). The findings recorded a path coefficient value of 0.707, with a t-value of 17.743 and a p-value of 0.000, thereby indicating a highly significant relationship. Among all direct relationships, SCC demonstrated the strongest influence on operational performance. This finding suggests that organizational culture capability, strategic sourcing capability, and trust-based collaboration substantially contribute toward operational responsiveness, reliability, and efficiency within cold storage operations (Kim, 2025). The result indicates that organizational capability remains a critical determinant of operational success regardless of technological integration intensity (Chatha et al., 2023).

Furthermore, H5, which proposed a relationship between Supply Chain Technology Adoption (SCTA) and Supply Chain Operational Performance (SCOP), was also supported. The findings recorded a path coefficient value of -0.380, with a t-value of 6.726 and a p-value of 0.000, indicating a statistically

significant relationship between technology adoption and operational performance. The negative coefficient suggests that ineffective or poorly integrated technological adoption may negatively influence operational performance outcomes. This finding may reflect implementation challenges within cold storage firms where technology systems are adopted without sufficient organizational alignment, training, or operational readiness.

Table 6 Path Coefficients and Hypotheses Testing Results for the Structural Model

Hypotheses	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
H1: SCMP -> SCTA	-0.541	-0.54	0.05	10.824	0
H2: SCC -> SCTA	0.01	0.01	0.047	0.21	0.833
H3: SCMP -> SCOP	-0.238	-0.24	0.056	4.22	0
H4: SCC -> SCOP	0.707	0.708	0.04	17.743	0
H5: SCTA -> SCOP	-0.38	-0.382	0.056	6.726	0

4.7 Mediation Analysis

Mediation analysis was subsequently conducted to examine the indirect effects of Supply Chain Technology Adoption (SCTA) on the relationships between Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), and Supply Chain Operational Performance (SCOP). The mediation assessment involved evaluating total effects, direct effects, indirect effects, bootstrapped confidence intervals, and mediation types.

The findings presented in Table 7 demonstrated that SCTA significantly mediated the relationship between SCMP and SCOP, thereby supporting H6. Specifically, the indirect effect recorded a coefficient value of 0.205, with a standard error value of 0.040, a t-value of 5.108, and a p-value of 0.000. In addition, the bootstrap confidence interval ranged between 0.135 and 0.291, which did not include zero, thereby confirming the significance of the mediation effect. The findings further revealed that the direct effect between SCMP and SCOP remained statistically significant, with a coefficient value of -0.238, a t-value of 4.220, and a p-value of 0.000. Consequently, the mediation effect was classified as complementary partial mediation. This finding indicates that Supply Chain Management Practices influenced Supply Chain Operational Performance both directly and indirectly through Supply Chain Technology Adoption.

The mediation result demonstrates that managerial practices associated with operational coordination, supply chain integration, and information sharing significantly affected technology adoption processes, which subsequently influenced operational performance outcomes within cold storage firms. However, the negative direct effect suggests that ineffective managerial integration may simultaneously weaken operational efficiency despite technological involvement. This finding reflects the operational complexity of cold storage environments, where technological systems alone may not fully compensate for managerial inefficiencies and fragmented coordination structures (Alherimi & Ben-Daya, 2025). Therefore, technology adoption functions as a complementary operational mechanism rather than a complete substitute for managerial effectiveness.

In contrast, H7, which proposed that SCTA mediates the relationship between SCC and SCOP, was not supported. The indirect effect recorded a coefficient value of -0.004, with a standard error value of 0.018, a t-value of 0.204, and a p-value of 0.838. Additionally, the bootstrap confidence interval ranged between -0.045 and 0.028, which included zero, thereby confirming the absence of a significant mediation effect. Consequently, the findings indicate that Supply Chain Technology Adoption did not mediate the relationship between Supply Chain Capabilities and Supply Chain Operational Performance.

Although the mediation effect was insignificant, the direct effect between SCC and SCOP remained highly significant, with a coefficient value of 0.707, a t-value of 17.743, and a p-value of 0.000. This finding suggests that organizational capabilities directly contribute toward operational performance improvements without requiring technological mediation. Within the context of Beijing's cold storage industry, organizational culture capability, strategic sourcing capability, and collaborative operational trust may independently strengthen operational responsiveness, reliability, and flexibility regardless of technology adoption intensity (Zhang, 2025).

Table 7 Mediation Analysis Results for the Indirect Relationships among Supply Chain Management Practices, Supply Chain Capabilities, Supply Chain Technology Adoption, and Supply Chain Operational Performance

Total Effect			Direct Effect			Indirect Effect							Hypothesis Result
Coefficient	T value	P value	Coefficient	T value	P value	Hypothesis	Coefficient	SE	T value	P value	Percentile Bootstrap 95% CI		Type of Mediation
											LOWER	UPPER	
0.205	5.108	0.000	-0.238	4.220	0.000	**H6: SCMP -> SCTA -> SCOP**	0.205	0.040	5.108	0.000	0.135	0.291	Complementary Partial Mediation
-0.004	0.204	0.838	0.707	17.743	0.000	**H7: SCC -> SCTA -> SCOP**	-0.004	0.018	0.204	0.838	-0.045	0.028	No Mediation

Figure 2 Structural Model Assessment of the Relationships among Supply Chain Management Practices, Supply Chain Capabilities, Supply Chain Technology Adoption, and Supply Chain Operational Performance

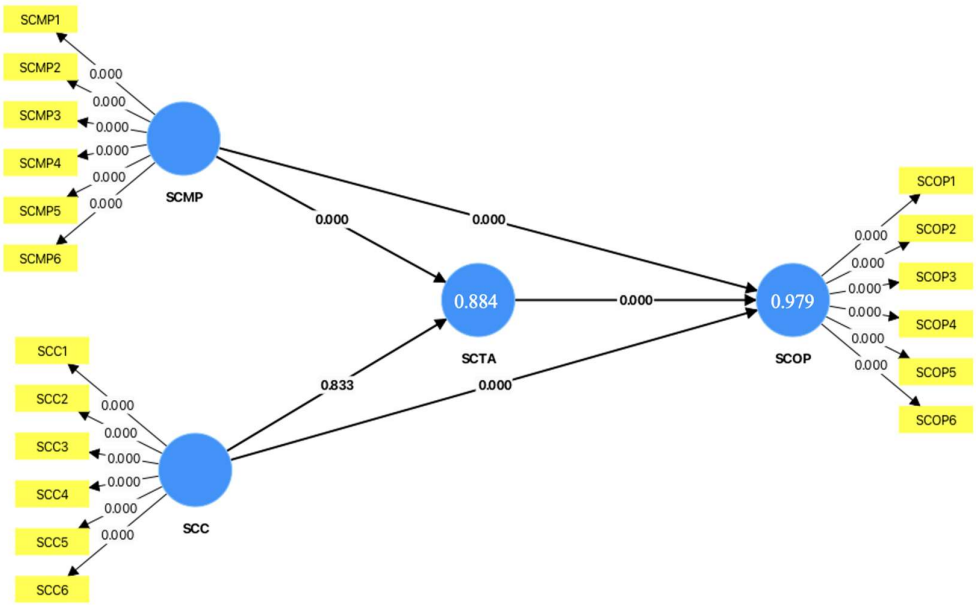

Figure 2 illustrates the structural model assessment generated through SmartPLS analysis for the proposed research framework. The figure presents the relationships among Supply Chain Management Practices (SCMP), Supply Chain Capabilities (SCC), Supply Chain Technology Adoption (SCTA), and Supply Chain Operational Performance (SCOP) within the cold storage industry in Beijing, China. The findings demonstrate that SCMP significantly influenced both SCTA and SCOP, while SCC significantly influenced SCOP but did not significantly influence SCTA, as indicated by the insignificant p-value of 0.833. Additionally, SCTA significantly influenced SCOP, confirming the importance of technological adoption in enhancing operational performance within cold storage operations. The figure also demonstrates high indicator reliability, whereby all measurement items achieved statistically significant loading values. Furthermore, the endogenous constructs recorded strong explanatory power, with SCTA and SCOP demonstrating adjusted R-square values of 0.884 and 0.979, respectively. Overall, the structural model confirms that organizational practices, technological adoption, and operational capabilities collectively contribute toward supply chain operational performance, while also demonstrating the mediating role of supply chain technology adoption within the proposed research framework.

5.0 Conclusion

This study examined the influence of Supply Chain Management Practices (SCMP) and Supply Chain Capabilities (SCC) on Supply Chain Operational Performance (SCOP) through the mediating role of Supply Chain Technology Adoption (SCTA) among cold storage firms in Beijing, China, grounded in the Technology-Organization-Environment (TOE) framework. The findings revealed that SCMP significantly influenced SCTA and SCOP, while SCC significantly influenced SCOP but demonstrated no significant relationship with SCTA. Furthermore, SCTA significantly influenced SCOP, confirming the importance of technological adoption in enhancing operational responsiveness, coordination, and efficiency within cold storage operations. The mediation analysis further demonstrated that SCTA

significantly mediated the relationship between SCMP and SCOP through complementary partial mediation, whereas no mediation effect was identified between SCC and SCOP. These findings contribute theoretically by extending the TOE framework through differentiated mediation effects within the cold storage supply chain context, while methodologically contributing empirical evidence through the application of PLS-SEM within China's logistics sector. Practically, the findings suggest that cold storage firms should strengthen managerial coordination, supply chain integration, information sharing, and technological infrastructure such as IoT monitoring systems, RFID tracking systems, and automated inventory management to improve operational performance and digital transformation readiness. Nevertheless, this study is limited by its cross-sectional design, industry-specific scope, and geographical concentration within Beijing, which may limit the generalizability of the findings to other industries and regions. Therefore, future research is recommended to adopt longitudinal approaches, expand the study across different logistics sectors and geographical contexts, and incorporate additional organizational or environmental variables to further strengthen the understanding of operational performance within evolving digital supply chain environments.

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