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Artificial Intelligence Adoption Model of Cold Chain Logistics Systems for Fresh Agricultural Products Enterprises in China

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Abstract

In recent years, the application of artificial intelligence in logistics services has shown significant growth in China. The significant growth has influenced other relevant sectors, including fresh agricultural products enterprises to adopt artificial intelligence in their business. However, it becomes challenging for the enterprises to adopt artificial intelligence due to lack of guidance for artificial intelligence adoption in cold chain logistics. This study aims to identify the factors influencing the adoption of artificial intelligence in the cold chain logistics systems of the enterprises dealing with fresh agricultural products. It begins with examining the current issues in Chinese cold chain logistics and the development of artificial intelligence. Following this, a model for artificial intelligence adoption in the cold chain logistics system of Chinese fresh agricultural product enterprises was developed based on Technology-Organisation-Environment framework and Diffusion of Innovations theory. The finding from this study will benefit the enterprises in meeting the Chinese government agricultural related policies. It also will benefit others who face decision making problems about artificial intelligence adoption in their enterprises.

Keywords: Artificial Intelligence, Cold Chain Logistics, Fresh Agricultural Products, Technology-Organisation-Environment, Diffusion of Innovations

Introduction

Chinese annual demands for fresh agricultural products, valued at trillions of dollars, have driven the rapid growth of cold chain logistics due to the development of e-commerce models and increasing market demand (Wang, 2022). However, the perishable nature of these products requires proper preservation measures to prevent spoilage and maintain their value during production, transportation and marketing (Ma et al., 2019). Effective management of cold chain logistics plays a crucial role in ensuring the quality and safety of fresh agricultural products throughout the entire supply chain.

However, the development of cold chain logistics in developing countries, such as China, faces

several challenges including outdated core technology, high logistics costs, energy consumption and frequent disruptions in the supply chain (Zhou et al., 2020). To address these issues, the future of cold chain logistics lies in the establishment of an integrated system that incorporates artificial intelligence (AI), cloud computing and the Internet of Things (IoT). The system would enable real-time monitoring, safety warnings and food traceability, thereby enhancing the efficiency and effectiveness of cold chain logistics (Han et al., 2021). By using IoT and cloud services, the AI cold chain logistics system could monitor temperature, humidity, geographical location and other relevant information across the entire supply chain through smart sensors. The approach enables comprehensive visual management of the entire process (Hou & Chen, 2022).

Furthermore, research on cold chain logistics in developed countries has extensively covered various aspects, but there is a lack of focus on AI adoption, especially in the field of fresh agricultural products (Pak, 2021; Neusel & Hirzel, 2022). Moreover, limited research has been conducted on developing countries, which play a significant role in the agricultural sector. As these countries experience economic growth, it becomes crucial for them to explore the potential benefits of integrating AI technologies into cold chain logistics systems.

China, as a developing country, has recognized the significance of AI in technological advancements and has actively pursued its development. In the realm of fresh agricultural products logistics and transportation, the traditional system encompasses various factors such as transport type and risk, logistics process operations and service conditions of logistics enterprises. These factors collectively influence the cost, quality, and management of logistics and transportation. Some scholars have explored how to use AI technology to build logistics systems (Huang & Guo, 2022; Yang, 2021). Li et al. (2020) focused on the Kiva mobile storage system and investigated the optimal storage allocation strategy, finding through simulation that it could improve the picking efficiency and reduce the energy consumption of Automated Guided Vehicles (AGVs) significantly. The research by Huang and Guo (2022), Yang (2021) and Li et al. (2020) focus on how to improve the cold chain logistics through the adoption of AI but lacks research on the factors affecting the adoption of AI in cold chain logistics system.

The Ministry of Transport in China issued the “Implementation Opinions on Accelerating the High-Quality Development of Cold Chain Logistics Transportation”, in alignment with the decisions and deployments of the Chinese State Council and the "14th Five Year Plan" for cold chain logistics development (The General Office of the State Council, 2021). With government support, the logistics and distribution networks in the supply chain of Chinese fresh agricultural products enterprises have made significant progress. The application of AI in coordinating innovative logistics activities has promoted the efficient operation of the entire supply chain (Zhu & Yin, 2020). AI has positively influenced the development of green technologies and the overall sustainable growth of the cold chain logistics industry. However, significant challenges still hinder AI’s widespread implementation in China. The challenges could be categorized into three main areas: high adoption cost, insufficient organizational capacity and unknown effect of environment. In China, both scholars and policymakers have emphasized the need for further research on AI adoption in logistics (Huang & Guo, 2022; Yang, 2021). Consequently, the paper aims to address existing research and practical gaps by focusing on the cold chain logistics system of fresh agricultural product enterprises in China. It seeks to investigate the adoption of AI in cold chain logistics systems by Chinese enterprises,

with the objective of identifying the factors that impact the adoption of AI in cold chain logistics and developing an appropriate model accordingly.

The first section of the paper introduces the background and defines its scope. It presents an overall summary of the whole paper. The second section digs into the literature review which includes comprehensive review of AI adoption of logistics system in China, the relevant technology acceptance theories and the research hypothesis. While the study applies the quantitative research method and a questionnaire survey, with the measurements of constructs presented at the last section of the paper.

Literature Review

The section provides the comprehensive review of current status and the research about the fresh agricultural product cold chain logistics in China. Moreover, it focuses on an in-depth overview of Technology-Organisation-Environment and Diffusion of Innovation, and operational definitions are shown in detail.

AI Adoption in Fresh Agricultural Products Logistics in China

In recent years, the Chinese government has actively implemented policies and regulations aimed at promoting rural revitalization (The State Council of the Central Committee of the Communist Party of China, 2020). The initiative is designed not only to foster the seamless integration of primary, secondary and tertiary industries, but also enhance rural industries through strategies involving industrial reconstruction, integration and innovation. A pivotal aspect of these efforts involves the establishment of cold-chain logistics for fresh agricultural products (Zhu et al., 2023). In China, the cold chain has become the focus of investment, including government support measures, industrial capital and venture capital (Wang, 2022). The influx of funds has significantly advanced the development of the cold chain infrastructure, particularly in expanding cold storage capacity. According to recent statistics, Chinese cold storage capacity increased from 36.09 million tons in 2017 to 52.24 million tons in 2021, demonstrating a compound annual growth rate of 9.7% (China Industry Research, 2023).

The support from national policies has propelled the vigorous development of Chinese cold chain logistics industry, evident in the notable surge in refrigerated trucks utilized for cold chain transportation. In 2019, the number of refrigerated vehicles reached 214,700 in China, reflecting a year-on-year increase of 19%, and the number rose to 341,600 in 2021 and further escalated to 369,000 in 2022 (China Industry Research, 2023). Despite these advancements, the logistics of Chinese fresh agricultural products has emerged as the focal point of research interest, drawing attention from scholars and researchers. Current research themes encompass various aspects, including the supply and demand dynamics of fresh agricultural products logistics, agricultural product infrastructure and cold chain logistics.

Diffusion of Innovation Theory

Diffusion of Innovation Theory, proposed by E.M. Rogers, defines diffusion as the process by which an innovation spreads over time through specific channels among members of a particular social system. Thus, there are four elements of diffusion: innovation, channel of diffusion, time and social system (Rogers, 1995). Therefore, DOI, which operates at the organizational level, is well-suited for integration with the Technology-Organization-

Environment framework.

Diffusion of Innovation theory suggests that the characteristics of innovations significantly influence the rate at which they are adopted and how quickly they diffuse (Rogers, 1995). Its characteristics include the following three factors: Relative advantages refer to the extent to that people perceive the advantage from adopting an innovation (Alsheibani et al., 2018). In the adoption process, it is not an inherent advantage of the technology that matters, but rather people's perception of its advantage. When an innovation is perceived to be more advantageous than its substitutes, it is adopted more quickly. Complexity refers to the perceived difficulty of understanding and using an innovation (Horani et al., 2023). Innovations that are perceived as more complex are adopted more slowly, whereas less complex innovations are easier to understand and adopt more quickly. Compatibility refers to the degree to that an innovation is consistent with the existing value, the past experiences and needs of the potential adopter (Liu & Cao, 2022). If an innovation does not align with these factors, it will not be adopted quickly. Since the application of Diffusion of Innovation to Information Systems research, DOI has been applied in lots of ways. However, research has consistently identified comparative advantages, complexity and compatibility as the main antecedents for innovation adoption (Bradford & Florin, 2003).

The DOI theory helps identify factors influencing organizational decisions regarding new technologies. Rogers (2002) summarized the basic principles of DOI through research, concluding that the diffusion process of new ideas and technologies follows an "S"-shaped curve. In the early stage, there are very few adopters, and the progress is very slow. In the diffusion of innovations, "early adopters" provide the necessary preparation for later take-off. This "small" group significantly influences communication and adoption rates (Rogers, 2002). Since the adoption of AI technology in cold chain logistics systems is still in the early stages, the top 500 fresh agriculture products enterprises in China have more financial and technical resources to take the risks associated with technology adoption.

DOI provides a framework for analyzing factors affecting the adoption of AI technology in cold chain logistics systems among Chines fresh agriculture products enterprises. In particular, the characteristics of innovation, Relative Advantage, Complexity and Compatibility (Rogers et al., 2014), which are useful for explaining the factors affecting the adoption of AI in the cold chain logistics system by fresh agriculture products enterprises at the level of technological characteristics. However, it could be seen that the DOI theory is over-simplifying the AI adoption of cold chain logistics, and it ignores the impact of organization differences and external environmental factors on fresh agriculture products enterprise (Lv et al., 2017). Therefore, it has to be combined with TOE to make up for the shortcomings and provides a more comprehensive analysis.

Technology-Organisation-Environment Framework

The field of technology acceptance is crucial for understanding how users adopt and use technology. Over the years, this area of research has evolved significantly, contributing numerous classical theoretical achievements. The central idea is that the value of information technology could only be fully realized when it is accepted and effectively used by users. Researchers have employed various theories to elucidate the adoption behavior and processes of IT and IS, adapting to the changing landscape of technology. The TOE framework

has gained significant traction in the field of IS and management. Proposed by Tornatzky and Fleischer (1990), the TOE framework serves as a robust analytical tool to understand the interaction between technology, organizational factors and the external environment.

The Technology-Organisation-Environment identifies three main components that influence technology adoption: a. Technological Context: It includes factors such as the complexity of technology, compatibility with existing systems and the level of innovation associated with technology. b. Organizational Context: The component focuses on internal organizational factors, such as organizational culture, resource and decision-making process. It acknowledges that successful adoption of technology is contingent on how well it aligns with the existing organizational context. c. Environmental Context: External factors, including market competition, regulatory environment and industry trends. The TOE framework recognizes that organizations operate within a broader context that could shape and constrain their technological decisions (Tornatzky & Fleischer, 1990).

Over the years, researchers have expanded and refined the Technology-Organisation-Environment to capture complexities of technology adoption better (Chatterjee et al., 2021). Modifications have been made to account for context, industry-specific considerations and the dynamic nature of technological advancements. Researchers have utilized the framework to investigate technology adoption patterns, understand the challenges faced by organizations and predict the technology implementations. By examining cases across different sectors, the TOE framework has demonstrated its versatility and applicability in capturing the unique characteristics of various organizational contexts (Bryan & Zuva, 2021).

TOE framework has emerged as a foundational model for understanding the intricate dynamics surrounding technology adoption in organizations. Its enduring relevance and adaptability across industries highlights its utility as a guiding framework for both research and practical applications. As technology continues to shape the business landscape, the TOE framework remains the valuable tool for researchers and managers seeking to navigate the multifaceted relationships between technology. With the rapid development of IT, researchers strive to refine existing models and propose new ones to capture the technology acceptance in different contexts. The ongoing research is vital for informing practitioners, policymakers and technology developers about the factors influencing user acceptance, in turn, which could guide the successful implementation of new technologies.

Hypotheses Development

The paper utilizes the Technology-Organisation-Environment combined with Diffusion of Innovation to investigate how technological factors (Technical Relative Advantage, Technical Complexity, Compatibility and Technology Adoption Costs), organizational factors (Top management support and Organizational readiness), environmental factors (Competitive Pressure, Government support and Vendor support) influence the adoption of artificial intelligence in cold chain logistics systems for Chinese fresh agricultural product enterprises:

Table 1
Operational Definition and Hypothesis

Constructs	Operational Definition	Hypothesis
Technical Relative advantage	Technical relative advantage refers to the relative advantage of adopting AI technology over other technologies (Oliveira et al., 2014;).	H1: Relative advantage would significantly influence the artificial intelligence adoption of cold chain logistics systems for fresh agricultural products enterprises in China.
Technical complexity	Technical complexity refers to the degree of difficulty with which fresh agricultural products enterprises could understand, implement and use AI technology (Rogers, 2003).	H2: The complexity of AI technology would significantly influence the artificial intelligence adoption of cold chain logistics systems for fresh agricultural products enterprises in China.
Technical compatibility	The extent to that fresh agricultural products enterprises adopt AI technology which integrates with the organization's existing processes, needs and infrastructure (Chatterjee et al., 2021).	H3: The compatibility of AI technology would significantly influence the artificial intelligence adoption of cold chain logistics systems for fresh agricultural products enterprises in China.
Costs	Technology adoption costs refer to the various costs incurred when enterprises adopt AI technology (Horani et al., 2023).	H4: Technology adoption costs would significantly influence the artificial intelligence adoption of cold chain logistics systems for Chinese fresh agricultural product enterprises.
Top management support	Level of support from top management when adopting AI technology in fresh agricultural products enterprises (Liu & Cao, 2022).	H5: Top management support would significantly influence the artificial intelligence adoption of cold chain logistics systems for Chinese fresh agricultural product enterprises.
Organizational readiness	The degree of organizational readiness refers to the preparation degree of enterprises' ability and willingness to adopt AI (Halpern et al., 2021).	H6: Organizational readiness would significantly influence the artificial intelligence adoption of cold chain logistics systems for fresh agricultural products enterprises in China.

Methodology

Research Design

The proposed study intends to employ quantitative research methodology. In the initial stage, a comprehensive examination of primary literature materials will be undertaken in order to identify and elucidate existing gaps in research. The subsequent stage involves the

establishment of a theoretical framework and formulation of research hypotheses. To achieve the more accurate and comprehensive understanding of AI adoption within cold chain logistics systems of Chinese fresh agricultural product enterprises, the study relied on relevant decision makers from each enterprise (top management and technical managers) as the principal source of data for the questionnaire. It is crucial to select Chinese fresh agricultural product enterprises as the organizational background for the sample selection.

Table 2
Measurements of Constructs

Construct	Code	Measurement issues	Reference
Technology Comparative Advantages	TCA1	Adoption of AI technology improved the operational and management efficiency of cold chain logistics systems.	Badi et al. (2021); Pan et al. (2021); Chen et al. (2019); Maroufkhan et al. (2020); Horani et al. (2023); Liu & Cao (2022)
	TCA2	Adoption of AI technology enhanced data and information sharing among cold chain logistics systems.	
	TCA3	Adoption of AI technology enhanced traceability and transparency in cold chain logistics.	
	TCA4	Adopting of AI technology reduced transaction costs in cold chain logistics.	
Technical Complexity	TCO1	The skill required to use AI technology is too complex.	
	TCO2	The process of adopting AI technology to the cold chain logistics system is very challenging.	
	TCO3	AI technology adoption requires sufficient experience.	
Technical Compatibility	TCB1	Adoption of AI is compatible with the enterprises' existing hardware and software environment.	
	TCB2	Adoption of AI is compatible with the enterprises' current production operation.	
	TCB3	Adoption of AI is compatible with the enterprises' current infrastructure.	

Conclusion

The paper has successfully developed a theoretical framework that advances knowledge in the field and serves as a valuable resource for future research. Additionally, the paper offers a novel perspective on logistics studies by discussing the influencing factors of the AI adoption in cold chain logistics from a distinct standpoint. Theoretically, Technology Comparative Advantages, Technical Complexity, Technical Compatibility, Technology Adoption Costs, Top Management Support, Organizational Readiness, Competitive Pressure, Government Support

and Vendor Support are the main variables that are found to be significant to AI technology adoption, though empirical data is required to validate these connections. The model would provide implications for practitioners, in particular for decision makers and managers of fresh agricultural product enterprises, intelligent cold chain logistics systems providers and policy makers. Furthermore, the framework utilized in the paper is constructed based on previous literature, which limits its generalization. Therefore, it is recommended that further research be conducted in other regions and with different drivers to validate the findings of the paper.

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