MiniReview

Development of Cold Chain Logistics for China’s Fresh E-commerce in Post-Epidemic Era

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Abstract

The emergence of the COVID-19 pandemic presented both unprecedented challenges and remarkable opportunities for China’s fresh food e-commerce industry. This dynamic landscape has underscored the critical importance of advancing cold chain logistics within this industry. Drawing upon established supply chain management theories, this paper identifies key areas for enhancement in the realm of cold chain logistics for fresh e-commerce. Through a comprehensive review of existing literature and current research findings, this study delves into the current state of cold chain logistics for fresh e-commerce, scrutinizing prevalent issues and deriving significant insights. The paper advocates for enterprises to prioritize the integration of cutting-edge technologies, enabling the creation of intelligent logistics systems. Additionally, it emphasizes the implementation of lean supply chain management practices to drive holistic regional development. Furthermore, leveraging policy support for the expeditious establishment of industry standards and protocols is crucial. The conclusions drawn from this research hold tangible implications for understanding the present landscape of cold chain logistics in fresh e-commerce, offering a theoretical and practical foundation to propel its future development.

Keywords: fresh e-commerce, cold chain logistics, post-epidemic era, smart logistics

1 INTRODUCTION

Fresh e-commerce refers to the use of Internet platforms for the direct sale of fresh products to customers⁰. Aligned with the general trend of e-commerce, fresh food e-commerce embodies the essence of online commercial transactions. The year 2012 is widely recognized as the inaugural year of the development of fresh food e-commerce in China. With the development of the economy and society and the improvement of residents’ consumption level, the demand for fresh food has shifted towards considerations of diversity, safety, and sustainability.

Cold chain logistics plays a key and decisive role in the development of fresh e-commerce, constituting its fundamental underpinning. The cold chain logistics industry refers to the transportation and warehousing of goods that
necessitate specific temperature, humidity, and environmental conditions throughout the logistics process[2]. With the improvement of China's social economy and consumption level, the demand for sectors that hinge on temperature-sensitive goods - such as food, medicine, and cosmetics - continues to surge, accelerating the steady growth of the cold chain logistics industry. In 1980, the National Transportation Association of the United States introduced the concept of the “cold chain”, setting forth stringent requirements for temperature range, seamless transportation links, heightened service efficiency, rigorous hygiene management, and steadfast quality and safety standards[3]. The outbreak of COVID-19 in late 2019 prompted a surge in demand for fresh produce through contactless channels such as e-commerce, driven by consumers’ heightened focus on food safety and health. This surge, in turn, has catalyzed an exponential rise in the demand for cold chain services and the equitable allocation of resources within the cold chain industry. In recent years, China’s State Council, alongside local governments and pertinent industry associations, has consistently issued documents pertinent to the cold chain logistics sector currently lags. To better align with the evolving demands of fresh e-commerce, an urgent transformation and upgrade of cold chain logistics for fresh products is imperative.

This article aims to investigate the current status and address development challenges in cold chain logistics for fresh e-commerce through the analysis of supply chain management theories. Beginning with an examination of the historical context of fresh food e-commerce and its intricate connection with cold chain logistics, we will delineate the research inquiries that have emerged. Employing a combination of literature review and real-world case studies, we will analyze and discuss these questions, ultimately proposing a series of pragmatic solutions. Through combing the relevant research, it becomes evident that cold chain logistics is crucial to the development of fresh e-commerce. However, significant issues persist in the domains of large-scale cold chain operations, facility utilization, standard systematization, and informatization. In response to these challenges, we put forward relevant suggestions to optimize the cold chain logistics path of China’s fresh food e-commerce cold chain logistics.

This article conducts thorough research on the current state of cold chain logistics for fresh e-commerce. It offers viable adjustments and suggestions grounded in supply chain management principles. These encompass the integration of cutting-edge technologies to establish intelligent logistics, the implementation of lean supply chain management practices, the promotion of regional coordinated development, and the pursuit of standardization and normalization. These recommendations hold the potential to optimize cold chain logistics operations, reduce associated costs, enhance efficiency, and bolster the sustainable evolution of the supply chain. It is hoped that this paper will serve as a valuable reference for both academic research and practitioners in the field of business management.

2 LITERATURE REVIEW
2.1 Status Quo of Research

In the realm of fresh food e-commerce, cold chain logistics emerges as a crucial and determining factor, forming the bedrock for the advancement of the entire sector[4]. Through the analysis of existing market demand data, researchers have used network simulation methods to predict the future five-year demand for cold chain logistics in China’s fresh agricultural products[5]. The resulting conclusion underscores the development potential within the domain of cold chain logistics. In the post-pandemic era, China’s logistics industry is poised for rapid evolution propelled by three key drivers, namely, market forces, technological advancements, and policy shifts. This transformation is anticipated to catalyze significant shifts in five pivotal dimensions - namely, logistics demand, supply, infrastructure, informatization, and overall industry development[6].

However, despite its potential, the development of cold chain logistics still faces many challenges[7]. Currently, obstacles hindering the development of cold chain logistics in China include uneven distribution of cold chain infrastructure, insufficient supporting facilities, suboptimal informatization level, limited scale of enterprises, shortages in professional expertise and financial resources, and a deficiency in comprehensive regulatory frameworks[8]. At a macroscopic level, the slow and incomplete progression of cold chain scaling processes has led to a mismatch between the development speed of cold chain logistics and the fresh food e-commerce sector. From a more granular perspective, opportunities abound for enhancing innovation capacity, information coordination proficiency, and overall industry awareness of business entities[9]. The cold chain logistics industry still needs more standardized and refined industry standards.

To address these issues, scholars have put forward targeted suggestions for further developing and improving cold chain logistics for fresh food e-commerce from multiple perspectives. These encompass logistics information systems, cold chain logistics equipment, standard systems, and technology. Strengthening food traceability can be achieved through measures such as transportation monitoring platform construction, enhanced coordination and control by management departments, and improved information intelligence levels[10]. Cold chain enterprises should focus on technological applications and diversification of product categories, while simultaneously prioritizing the construction and optimization of cold chain logistics facilities to reduce
energy consumption and costs\cite{11}. Simultaneously, emphasis is placed on advancing the cold chain scaling process in the context of rapid e-commerce development, along with the necessity of establishing a standard system and increasing the level of marketization. Achieving the dual goals of low carbon footprint and intelligent innovation necessitates collaboration between national regulatory agencies, industries, consumers, and interdisciplinary experts\cite{12}. The industry’s overall development is promoted through the dual impetus of policy support and industry norms.

The impact of the COVID-19 pandemic has highlighted the importance of establishing high-quality cold chain logistics for fresh food e-commerce. In the subsequent section, we review international studies on the development of cold chain logistics for fresh food e-commerce in the post-pandemic era. Through an examination of the pandemic’s influence on global supply chains, it is underscored that enhancing supply chain resilience stands as a pivotal driving force in mitigating vulnerability during tumultuous periods\cite{13}. Additionally, attention to improved strategies for relocation and reshoring in the post-pandemic era is posited to lead to a reduction in the length of global supply chains\cite{14}.

In terms of technology, the application of advanced technologies, particularly artificial intelligence, holds significant importance\cite{15}. Numerous studies underscore the substantial potential of technologies like artificial intelligence in propelling the development of logistics. Researchers advocate for the utilization of Internet of Things (IoT) technology to implement lean management, thereby augmenting the efficiency of logistics processes. This involves the integration of technologies such as blockchain, robotics, big data analysis, and cloud computing in the management of cold chain logistics\cite{16}. For example, AI-based predictive analytics exhibit promise in optimizing inventory management, curbing waste, and enhancing overall supply chain efficiency\cite{17}. Additionally, attention has been directed towards initiatives such as establishing an IoT-driven multi-level agricultural food supply chain, refining ant colony optimization algorithms for cold chain distribution route optimization, and delving into the intricacies of cold chain logistics distribution\cite{18}.

Furthermore, the research places substantial emphasis on consumer-oriented approaches\cite{19}. Investigations into the elasticity effects of food consumption behavior during the COVID-19 period in Italy highlight the critical role played by personalized marketing strategies, reliable delivery services, and comprehensive product information in cultivating consumer trust and satisfaction\cite{20}. The significance of home delivery services in aiding vulnerable consumers in bridging the digital divide, while also affording opportunities for small-scale retailers and producers, is underscored\cite{21}. An evaluation framework for food cold chain logistics enterprises is established, encompassing four crucial facets: financial management, cold chain logistics processes, development capabilities, and customer service.

In terms of sustainable development of global supply chains, there have been recommendations for optimizing logistics systems. The importance of establishing sustainable and resilient food systems for the stability and longevity of food supply chains is underscored. Additionally, cooperative efforts among cold chain enterprises are viewed as a contributing factor to the sustained development of the industry in the post-pandemic era. Exploring the development path of agricultural product cold chain logistics in a low-carbon environment helps promote the sustainable development of food cold chains, particularly in light of global warming challenges\cite{22}.

In summary, the findings of these studies emphasize the pivotal roles of advanced technology, robust infrastructure, data analysis, and consumer-centric approaches. These insights offer valuable guidance for the Chinese government, logistics providers, and e-commerce platform-related companies to enhance the efficiency, safety, and reliability of China’s cold chain logistics system. This, in turn, facilitates the timely and precise delivery of fresh, high-quality food to consumers.

2.2 Summary of the Literature Review

Comprehensive literature reviews conducted by both domestic and international scholars have yielded a wealth of research on cold chain logistics for fresh e-commerce. Within this body of work, the predominant focus lies on the study of fresh product packaging\cite{23}, transportation, and related demand characteristics as well as consumer preferences. Many macro-level analyses draw from classic e-commerce enterprise cases as illustrative evidence. Additionally, some scholars have delved into optimizing cold chain transportation routes\cite{24}, demand forecasting, and cost control. A majority of these studies employ virtual enterprises as the subjects for model analysis, with some extending their scope to encompass the selection of transportation equipment such as refrigerated trucks. Moreover, a notable subset of scholars has explored issues pertaining to sustainability and carbon neutrality, contemplating the ecological sustainability of fresh e-commerce cold chain logistics. Building upon this foundation, our paper seeks to continue, complement, expand, and innovate upon this existing research.

However, we have identified several notable gaps in the current body of literature. Firstly, existing studies, both domestic and international, often lack a systematic analysis of cold chain logistics, particularly in terms of its macro system operation encompassing logistics transportation, warehousing, distribution, and related links. This deficiency results in challenges to pinpoint areas for optimization to reduce the costs associated with cold chain logistics.
Secondly, there exists a relative paucity of in-depth research on third-party service platforms within cold chain logistics. The pivotal role of these platforms in the overall operation of the cold chain system has been largely overlooked. The third-party cold chain logistics service platform has long-term significance for the whole cold chain system to improve quality and efficiency, reduce cost, and provide logistics operation guarantees.

Thirdly, while both domestic and international literature has explored the technical aspects of cold chain logistics development, there remains room for further examination. It is evident that advanced cold chain technology plays a fundamental role in driving innovation and progress within the field, offering fresh perspectives on how China’s cold chain logistics can be better developed to meet the demands of the fresh produce e-commerce industry.

3 DEVELOPMENT STATUS OF COLD CHAIN LOGISTICS FOR FRESH E-COMMERCE

3.1 Information Technology to Enable the Wisdom of Cold Chain Logistics

Big data represents a significant milestone in the ongoing industrial revolution of information technology, following in the footsteps of the Internet, IoT, and cloud computing. Its rapid development has not only improved the coordination and decision-making capabilities of cold chain logistics enterprises, hastening the progress of cold chain logistics informatization, but has also brought personalized and high-quality business policies for agricultural products e-commerce. The adept utilization of technology can effectively manage cost inputs across the entire cold chain while meeting the market demand for high-quality agricultural products.

With the intelligent digitization of cold chain operations, the trajectory towards intelligent cold chain logistics is set to define the future of the industry. Combined with the unique characteristics of the fresh product field, and leveraging technologies such as the IoT and big data, the logistics system’s management decision-making and implementation capabilities, as well as the overall system’s level of intelligence, are poised for augmentation. This transformation constitutes a pivotal means for cold chain logistics enterprises to enhance their differentiation advantage.

3.2 The Epidemic Has Stimulated the Increasing Market Demand for Fresh Products

The sudden outbreak of the COVID-19 pandemic in 2020 precipitated a paradigm shift towards online shopping and consumption to fulfill fresh food requirements. E-commerce platforms emerged as pivotal channels for individuals to access fresh produce. As per the CDP2020 China Supply Chain Report, China’s fresh produce e-commerce market expanded to 263.84 billion yuan in 2020, reflecting an impressive growth rate of 62.9%.

According to Quest mobile data, the outbreak led to a net addition of 25.42 million new users in China’s fresh produce e-commerce sector. This shift towards online consumption of fresh food, catalyzed by the pandemic, persisted even after the situation was brought under control. In 1-3 tier cities, where hourly fresh food e-commerce models predominate, convenience surpasses that of traditional large supermarkets. In 4-6 tier cities, community group purchases represent a more cost-effective alternative to conventional sales channels. Statistics further affirm that 65.4% of Chinese fresh food e-commerce consumers increased their spending in 2021, with 51.6% allocating higher budgets. Consumer frequency and expenditure on online fresh food shopping continue to exhibit an upward trajectory.

3.3 The Cold Chain Logistics of Fresh Products Has a Great Development Trend

Under the unique circumstances of the epidemic, the quality standards for low-temperature preservation and distribution of fresh products have witnessed a continual enhancement. China’s cold chain logistics industry has ushered in its golden period of development. Data show a substantial surge in China’s cold chain logistics market, escalating from 331.9 billion yuan in 2019 to 383.2 billion yuan in 2020, marking a noteworthy 13% year-on-year increase. The aggregate demand for cold chain services surpassed 265 million tons, reflecting a 13.69% year-on-year upswing. In cold chain logistics, the demand for food cold chain constitutes nearly 90% of the overall requirement. Referencing Table 1, it becomes evident that the demand for the cold chain logistics industry exhibits a consistent upward trajectory. This underscores the pivotal role of fresh product cold chains in propelling the holistic advancement of the cold chain industry.

3.4 Relevant Support Policy System is Gradually Improving

Since the onset of the epidemic, there has been a noticeable uptick in the formulation of cold chain policies across various sectors. In November 2020, the state released a policy entitled “Notice on Further Improvement of Cold Chain Food Traceability Management”. This directive advocates for bolstering the coordination and interconnection of relevant departments, with a focus on implementing an information registration system. Additionally, it emphasizes the achievement of comprehensive information traceability for key cold chain foods, spanning from customs import inspection to storage and distribution, production and processing, wholesale and retail, as well as food service. The policy also underscores the establishment of a swift and precise response mechanism for handling problematic products.
In recent years, China’s State Council, along with governments at various levels and industry associations, have consistently issued a series of documents related to the cold chain industry. Table 2 provides an overview of some key documents and their related content released by China within the past five years. This concerted effort underscores the nation’s steadfast commitment to advancing the development of cold chain logistics. It also foreshadows that the country will promote the development of cold chain logistics with greater efforts in the new development paradigm.

4 DEVELOPMENT OF COLD CHAIN LOGISTICS FOR FRESH E-COMMERCE

4.1 The Shortcomings of the Cold Chain Logistics Informatization Process are Obvious

The core of cold chain logistics lies in the precise control of temperature and real-time monitoring, underscoring the critical importance of seamless connectivity between refrigerated containers during transportation and across different logistics links. However, significant deficiencies persist in the realm of tracking and monitoring technology. Presently, the traceability system for agricultural products’ cold chains cannot cover all upstream and downstream nodes, rendering real-time personnel supervision and product monitoring during transportation unattainable. This deficiency was particularly evident during the COVID-19 epidemic, where inadequate monitoring of transmission pathways contributed to widespread transmission. Furthermore, the integration level within China’s cold chain logistics industry remains notably low, with a pronounced disparity in informatization levels across different entities.10. Data formats and standard specifications differ between different companies, and product information at various stages is often scattered across various departments within supervisory bodies or cold chain enterprises, hindering seamless information integration. In instances of food transportation accidents spanning multiple regions, supervisory bodies often struggle to determine legal responsibilities due to information gaps, and ensuring the standardization and authenticity of information is difficult to guarantee.

4.2 Construction Cost of Cold Chain Logistics for Fresh E-commerce Remains High

According to data from China Cold Chain Logistics Network, the proportion of using cold chain transportation facilities for perishable products in China is only 10%-20%. The rate of decay for agricultural products is 25%-30%, and the average loss rate for fresh produce is above 10%. Notably, the rate of decay for fresh products in China is significantly higher than that of developed countries. In response to the high cost of cold chain standard packaging, some businesses opt for more budget-friendly alternatives such as ice cubes and foam boxes for transportation30. It is estimated that cold chain disruptions in China cause the waste of approximately 12 million tons of fruit and 130 million tons of vegetables annually, resulting in economic losses exceeding hundreds of billions of yuan. The costs associated with product damage account for a staggering 70% of the entire transportation product costs, markedly surpassing international standards. Moreover, the pandemic has dealt a significant blow to cold chain logistics enterprises, resulting in substantial human and material resource losses. Data shows that, in 2020, 81.5% of enterprises experienced an increase in labor costs. The industry’s impaired operational capacity has led to continuous losses of enterprises, directly affecting their subsequent development and improvement of the system.

4.3 Construction of Cold Chain Logistics and Transportation Network is Not Perfect

The eastern region of China boasts a high level of economic development, characterized by well-established infrastructure and relatively low entry costs for businesses. However, the central and western regions are suffering from severe aging and lack of technological innovation. These factors impede local investment attraction and contribute to a notable outflow of skilled labor. Furthermore, the absence of industry-leading enterprises further hinders the development of cold chain logistics in these areas. Inequities in road construction standards across the country exacerbate the difficulty of extending cold chain supply chains to remote regions. Additionally, a scarcity of composite talents and individuals capable of coordinating and orchestrating multi-modal transportation networks also poses a significant obstacle to supporting the operations of cold chain enterprises in multi-modal transportation. Consequently, the regional development divide in China’s cold chain logistics continues to widen.

Therefore, constructing a comprehensive transportation network system for cold chain enterprises is becoming increasingly urgent. The differences in the proportion of enterprises by region in China are shown in Table 3.

4.4 China’s Policy or Cold Chain Logistics Industry Support Lacks Precision

In recent years, China has introduced many policies to support the development of cold chain logistics. However, most of these policies lack precise support.

Table 1. China’s Total Cold Chain Logistics Demand and Forecast from 2017 to 2022

<table>
<thead>
<tr>
<th>Year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total demand (tons)</td>
<td>14,750</td>
<td>18,870</td>
<td>23,308</td>
<td>26,500</td>
<td>27,460</td>
<td>32,450</td>
</tr>
</tbody>
</table>


https://doi.org/10.53964/mem.2023013
Table 2. Important Policies Documents on the Development of Cold Chain Logistics in China in the Past Five Years

<table>
<thead>
<tr>
<th>Year of Promulgation</th>
<th>Agency of Promulgating</th>
<th>File Name</th>
<th>Content about Cold Chain Logistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>February, 2019</td>
<td>General Office of the State Council, PRC</td>
<td>“Opinions on Promoting the High-quality Development of Logistics and Promoting the Formation of a Strong Domestic Market”</td>
<td>Enterprises are encouraged to innovate the cold chain logistics infrastructure business model and develop a third-party cold chain logistics monitoring platform.</td>
</tr>
<tr>
<td>February, 2020</td>
<td>General Office of the State Council, PRC</td>
<td>“Opinions of the CPC Central Committee and the State Council on Grasping the Key Work in the Field of “Three Rural Areas” to Ensure the Realization of All-round Moderate Prosperity on Schedule”</td>
<td>Start the construction project of cold chain logistics facilities for the storage and preservation of agricultural products.</td>
</tr>
<tr>
<td>February, 2021</td>
<td>General Office of the State Council, PRC</td>
<td>Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting Rural Revitalization and Accelerating the Modernization of Agriculture and Rural Areas</td>
<td>Accelerate the implementation of the construction of cold chain logistics facilities for the storage and preservation of agricultural products.</td>
</tr>
<tr>
<td>November, 2021</td>
<td>National Development and Reform Commission, PRC</td>
<td>“14th Five-Year Plan” Cold Chain Logistics Development Plan</td>
<td>By 2025, a cold chain logistics network that connects the place of origin, covers urban and rural areas, and connects domestic and international will be initially formed.</td>
</tr>
<tr>
<td>February, 2022</td>
<td>General Office of the State Council, PRC</td>
<td>“Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting the Key Work of Rural Revitalization in 2022”</td>
<td>Promote the extension of the cold chain logistics service network to rural areas, and improve the quality and safety traceability system of the whole industrial chain of edible agricultural products.</td>
</tr>
<tr>
<td>February, 2023</td>
<td>General Office of the State Council, PRC</td>
<td>“Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting the Key Work of Rural Revitalization in 2023”</td>
<td>Support the construction of a cold chain distribution center in the place of origin. Coordinate the prevention and control of the epidemic and the market supply of agricultural products.</td>
</tr>
</tbody>
</table>

The most representative area of weakness is the First Kilometer, which constitutes a critical link in the pre-management of cold chain logistics. Firstly, the investment policies introduced by national and local governments are not sufficiently precise, failing to provide adequate guidance and incentives for large e-commerce companies. Secondly, local governments have an inadequate understanding of the cold chain industry. Issues such as poor coordination among different departments and conflicting policies among various government agencies are common issues. Additionally, there exists a scarcity of specialized talent at the grassroots level in the field of cold chain logistics. Finally, the government’s efforts to establish a favorable business environment fall short. The absence of standardized, scientific, systemic, information-based, and modern pre-management practices constrains the traceability of fresh products. In the collaborative efforts between e-commerce companies, third-party cold chain service providers, and the grassroots production areas, the government does not offer proactive guidance and support.

Overall, China’s guidance policy system for cold chain logistics remains incomplete. The industry’s development requires more precise and powerful policies to provide support.

5 MEASURES TO IMPROVE COLD CHAIN LOGISTICS FOR FRESH E-COMMERCE

5.1 Build a Smart Cold Chain Service Platform Driven by the IoT

5.1.1 System Design of Smart Cold Chain Service Platform

The intelligent cold chain logistics platform of the IoT combines a new generation of Things technology with intelligent cold chain technology to create a system that can achieve cold chain logistics management. With stable technical support spanning from sensors to IoT devices, the platform ensures the reliability and stability of IoT operations. Its overarching goal is to interconnect enterprises across different facets of cold chain transportation, forging a seamless continuum from origin to sales. It aims to promote the industry standardization of cold chain logistics, the standardization of cold chain supervision, and the integrity of information traceability.
Table 3. Distribution of Cold Chain Logistics Enterprises in China in 2021

<table>
<thead>
<tr>
<th>Area</th>
<th>Proportion of the Number of Enterprises</th>
<th>Area</th>
<th>Proportion of the Number of Enterprises</th>
</tr>
</thead>
<tbody>
<tr>
<td>East China Region</td>
<td>32%</td>
<td>Central China</td>
<td>9%</td>
</tr>
<tr>
<td>North China</td>
<td>17%</td>
<td>Northwest Territories</td>
<td>8%</td>
</tr>
<tr>
<td>South China</td>
<td>16%</td>
<td>Northeast China</td>
<td>8%</td>
</tr>
<tr>
<td>Southwest Region</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


5.1.2 Design of the Technical Architecture of Smart Cold Chain Logistics Platform

According to the hierarchical structure of the IoT, the architecture of the platform is as follows: First is the sensor perception layer. At this foundational layer, the platform achieves comprehensive monitoring of key indicators throughout the cold chain logistics process. This is accomplished by installing temperature and humidity sensors and employing sensing technologies such as Web GIS. Additionally, technologies such as RFID and Wireless Sensor Networks ensure that the key parameters of these fresh product environments meet specified requirements, with data subsequently uploaded to the cloud[33]. This layer also enables remote viewing and monitoring of transport vehicles, facilitating the optimization of distribution paths.

The second is the cloud processing layer. Responsible for transmitting data collected by the sensor perception layer to the cloud through the IoT protocols, the cloud processing layer handles data processing and analysis. Cloud computing and big data analysis technologies are leveraged to provide real-time monitoring of temperature, humidity, transportation speed, and other pertinent transportation environment parameters for fresh products. Based on these data, the platform can make corresponding adjustments and offer prediction, early warning, and traceability query functions, which can make cold chain logistics more intelligent.

Third is the mobile application layer. Through integration with mobile applications and e-commerce platforms, this layer facilitates end-to-end visualization and streamlined services such as online ordering, payment, and distribution. It enables real-time supervision of the entire process - from fresh product harvesting to pre-cooling treatment, packaging, and transportation - via instantaneous information transmission, thereby ensuring effective data collection and traceability[34]. It can also provide consumers with APP applications to view the transportation process of fresh products in real-time, which is convenient for consumers to have a clearer understanding of the quality, safety, and transportation mode of fresh products[35].

5.1.3 Design of Emergency Dispatch Mechanism

The smart cold chain service platform collects and compiles epidemic-related data, facilitating the comprehensive analysis and evaluation of risk statuses within logistics networks. Each cargo’s receiving, sending, storage, and transportation routes are diligently recorded, providing a complete and traceable record for emergency response. Besides, the platform maintains constant communication with the deployment center, ensuring real-time updates on material demand and affected area information. Importantly, the platform possesses the capability to craft judicious distribution paths and methods to mitigate the risk of cross-infection.

The platform’s real-time monitoring extends to the health status of delivery vehicle drivers. In the event that an employee detects a suspected disease, the platform promptly notifies the relevant departments and initiates infectious disease screening[36]. Leveraging an intelligent communication system, the platform disseminates epidemic-related information to customers and employees, safeguarding their health and well-being. At the same time, stringent measures are implemented to prioritize information security, guarding against both inadvertent disclosures and malicious cyber threats.

5.2 Implement Lean Management of Cold Chain Supply Chain

5.2.1 Use Modern Warehousing Technology to Optimize Inventory Management

Fresh cold chain enterprises can optimize the existing cold chain warehousing system and update the intelligent warehousing technology and system through the intelligent cold chain platform. It can also realize an efficient and cost-effective warehousing operation mode. By using historical sales data, consumer purchasing patterns, and current market trends provided by the platform, enterprises can accurately predict future market demand, enabling them to formulate well-grounded procurement plans and implement effective inventory management strategies.

At the same time, the real-time monitoring system provided by the platform can help fresh cold chain enterprises to proactively manage their inventory, mitigating the risk of excessive backlog. This streamlined approach curtails inventory costs and ensures the consistent quality and supply of fresh products[37].
5.2 Use Big Data to Optimize the Cold Chain Logistics Path

The staff needs to comprehensively consider the attributes of the goods, customer needs and other factors and choose the best choice from a variety of transportation modes[38]. The platform employs relevant big data to draft transportation route plans tailored to different logistics needs. Additionally, it integrates a network system to monitor the real-time traffic status of the selected routes. Staff members can adjust the transportation route and reasonably arrange vehicles and distribution routes according to the real-time feedback of logistics and transportation services[39]. This approach minimizes goods transshipment, reduces transportation cost losses, and maximizes the efficiency of logistics transportation.

5.2.3 Focus on the Visualization of Temperature Control Monitoring Throughout the Whole Process

In the process of cold chain logistics transportation services for fresh products, the most effective intelligent technology should be selected for controlling temperature throughout the entire process, aligning with the specific needs of cold chain logistics. For example, temperature sensors should be strategically installed at every juncture of the cold chain logistics, ensuring continuous temperature monitoring[40]. By transmitting temperature data to the cloud, the regulatory department can conduct real-time assessments of the temperature variations within the entire cold chain logistics. This guarantees the safety and stability of fresh products throughout transportation and minimizes the loss rate. Ultimately, the adoption of such technologies enhances the quality and efficiency of cold chain logistics services.

5.3 Improve the Coordination and Allocation Mechanism of Cold Chain Infrastructure

5.3.1 Improve the Regional Coordination of Cold Chain Infrastructure Construction

Cold chain enterprises can make full use of the advantages of lower land prices, reduced labor costs, and policy support in the central and western regions. By increasing investments in local cold chain infrastructure and fostering the development of distinctive cold chain industry chains, enterprises can capitalize on the opportunities these regions offer. Local governments can promote the coordination of resources in the construction of cold chain logistics infrastructure through agreements, cooperative mergers, and acquisitions. This collaborative approach enables resource optimization and mutual benefits. It narrows the gap in the regional development level of cold chain logistics in China and enables enterprises to form agglomeration benefits and scale advantages.

5.3.2 Establish a Multimodal Transport System for Cold Chain Logistics

The formation of a cold chain logistics multimodal transport system is aimed at maximizing the advantages of various transportation modes and promoting their seamless integration[41]. Through innovation, it is necessary to accelerate the formation of a fresh cold chain multimodal transport system covering roads, railways and other ways. Cold chain enterprises should strategically plan transportation modes, enhance the coordination of operational information, and facilitate capacity arrangements among various transportation modes. This proactive approach includes optimizing and adjusting the transportation structure, ultimately transitioning toward the establishment of an intermodal and multimodal transport system.

5.3.3 Strengthen the Informatization Collaboration between Cold Chain Logistics Enterprises

To facilitate logistics information sharing, cold chain logistics enterprises can establish a common digital platform or participate in a cold chain enterprise alliance. Enterprises can open and share their spare equipment resources or build common infrastructure according to the needs of their peers on the platform. They can also strengthen academic exchanges and professional cooperation between regions to jointly study technical issues and facility innovation. By adopting these measures, enterprises can achieve mutual assistance and mutual benefit, ultimately realizing the objective of operating cold chain logistics with high efficiency and low costs. High-precision information transmission and sharing are paramount in ensuring the seamless circulation of the entire cold chain logistics industry chain.

5.4 Strengthen the Governmental Systematic Planning of Cold Chain Logistics

The first is to optimize the cold chain processing of storage links. The government should allocate special funds to incentivize the construction of warehouses and actively promote the upgrading of cold chain equipment and facilities. Streamlining the cold storage declaration audit process and expediting feedback on results are imperative steps to enhance the efficiency of storage operations.

The next step involves the integration of transportation resources and the enhancement of transportation standards. Firstly, the government should take the lead in driving technological innovation and providing robust scientific and technological support. Relevant departments should collaborate with research institutes and cold-chain logistics enterprises to spearhead technological advancements. This includes the development of large-scale refrigerated transportation equipment and the establishment of a standardized insulation transportation system. Secondly, third-party logistics enterprises should actively participate in the construction of a government-planned public service
cold chain logistics park. Such a park would serve as a multi-functional facility encompassing warehousing, distribution, and transportation. In particular, the government should pay attention to the construction of cold chain logistics parks for agricultural products in the central and western regions to regulate the contradiction between supply and demand.

Furthermore, the government should take on the role of providing policy guidance and regulation to ensure the effective operation of third-party cold chain logistics enterprises. These third-party logistics enterprises form the backbone of cold chain logistics market competition. The government should actively guide and accelerate the entry of third-party logistics enterprises and improve the marketization of cold chain logistics. Then, the government and e-commerce enterprises jointly build a rural supply and marketing integration platform. This platform can boost the level of industrialization for fresh products and promote a higher degree of supply and marketing integration. Ultimately, this initiative will lead to improved overall planning and integration of the upstream and downstream of cold chain logistics.

6 DISCUSSION

Based on the relevant theories of supply chain management and existing literature, this study identifies key areas for improvement in the development of cold chain logistics for fresh e-commerce. However, it is important to acknowledge the constraints of this study, including limited research capacity, resource availability, and data accessibility. These factors have influenced the following aspects that warrant further development and enhancement.

Limited by research ability and objective conditions, this study cannot examine the level of business flow, capital flow and knowledge flow in each supply chain. The study relies on publicly available information from node enterprises and industry sources. Nevertheless, to ensure the accuracy and integrity of data, future research should prioritize extensive investigations and data collection to validate findings.

Due to the particularity of data during the epidemic period and the influence of researchers’ own conditions, this paper chooses to combine the examples of some typical fresh food e-commerce enterprises for research, and at the same time takes a large number of research results in the same field at home and abroad as the theoretical basis. To enhance the practical applicability of research conclusions, future studies should aim to incorporate a wider range of cases and conduct more comprehensive analyses.

This study only considers the middle and lower reaches of fresh e-commerce enterprises, without delving into the role and selection of upstream suppliers. Future research endeavors should expand the scope to encompass upstream partners, recognizing their significant impact on the development of fresh e-commerce enterprises.

In summary, the exploration of challenges and proposed solutions in the development of fresh agricultural products and e-commerce cold chain logistics in China is an ongoing process. To further enhance the competitiveness of the industry and related enterprises, there is a critical need for deeper theoretical research, as well as empirical studies conducted on a broader scale. This will provide invaluable insights for China’s fresh cold chain logistics industry to navigate and thrive in this dynamic landscape.

7 CONCLUSION

This study underscores the exceptional growth potential of cold chain logistics for fresh e-commerce in China. The surge in market demand has catalyzed rapid innovation and advancement to meet evolving consumer needs. Concurrently, the rapid development of science and technology provides a wealth of resources to drive progress, while robust government attention fosters a stable and conducive environment for cold chain logistics development. However, this study also unveils the challenges behind the opportunities. The limited informatization of China’s cold chain logistics is a key constraint to break through its own development, impeding its full-scale potential. The high cost associated with fresh cold chain operations stands as a formidable barrier to overcome. Achieving regional infrastructure equilibrium is pivotal for extending the coverage of fresh product cold chain logistics across the nation. Furthermore, the precision and execution of policies play a decisive role in standardizing the fresh cold chain logistics industry. These perspectives are addressed comprehensively in this study.

To effectively enhance China’s fresh e-commerce cold chain logistics, a series of strategic measures are imperative. We propose the following recommendations for both fresh cold chain enterprises and the government:

(1) Building an intelligent cold chain service platform driven by the IoT.

(2) Implement lean management in the practical cold chain supply chain using modern technology.

(3) Improving regional coordination of cold chain infrastructure construction.

(4) Strengthening the systematic planning of cold chain logistics for government.

(5) Integrating the above measures with other established cold chain improvement initiatives, significantly contributing to the continued improvement of cold chain logistics for China’s fresh e-commerce.

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The authors declared no conflict of interest.

Author Contribution
Conceptualization was conducted by Sun X and Yuan Y; The original draft preparation was undertaken by Sun X, Yuan Y, Zhang G, and Tian L; Sun X and Sun H were responsible for writing, reviewing, and editing the manuscript; Wang X supervised the project and handled project administration; All authors have read and agreed to the published version of the manuscript.

Abbreviation List
IoT, Internet of Things

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