Research on the development strategy of China Southern Airlines cold chain logistics

Ling Li

Haaga-Helia University of Applied Sciences

Aviation business

Bachelor's Thesis

2025

Abstract

Author(s)
Ling Li

Degree
Bachelor of Business Administration, Aviation Business

Report/Thesis Title
Research on the development strategy of China Southern Airlines cold chain logistics

Number of pages and appendix pages
25+0

With the increasing prosperity of the cold chain logistics market, aviation cold chain logistics has become an extremely critical link in the cold chain logistics field with its outstanding timeliness and unique advantages of long-distance transportation. As a large and influential airline in China, China Southern Airlines plays an important role in the field of cold chain logistics and plays an important role. This article conducts an in-depth analysis of the current development status of China Southern Airlines' cold chain logistics and accurately finds out the core problems.

At the same time, we will draw on the advanced experience in the field of international aviation cold chain logistics and fully combine the actual development of my country's aviation cold chain logistics industry to put forward a series of strategic suggestions that are both targeted and forward-looking. Its purpose is to provide a practical and effective reference for the high-quality development of China Southern Airlines' cold chain logistics, and also help promote the further development of my country's entire aviation cold chain logistics industry.

Key words
China Southern Airlines, Cold Chain Logistics, Development Strategy, Air Transport, Logistics Management

Table of contents

1 Introduction

1.1 The Research Background

The global cold chain logistics market is experiencing robust growth. According to forecasts, its scale is projected to reach US$585 billion by 2027, with a stable average annual growth rate of 7.5%. As the world's largest consumer of fresh food, China has witnessed a rapid increase in demand for cold chain logistics, with an annual growth rate exceeding 15%. However, the industry standardization rate stands at only 22%, significantly lagging behind that of developed countries and regions such as Europe and the United States. The cold chain logistics sector is characterized by its strong timeliness and unique advantages in long-distance transportation, making it a critical component of the overall cold chain logistics landscape. China Southern Airlines, as a large and influential airline in China, plays a pivotal role in this field. In 2024, the company successfully surpassed the 9 billion yuan mark in its aviation logistics business. Nevertheless, the lag in technological updates and the financial challenges faced by the parent company severely restrict the further expansion and deepening of its cold chain business. Given this context, this study aims to provide a practical and feasible strategic development path for China Southern Airlines to overcome existing bottlenecks and achieve sustainable development.

1.2 Aim of the Research

The purpose of this research is to conduct an in-depth analysis of the current development status of China Southern Airlines' cold chain logistics, accurately identify the core issues, and draw on the advanced experiences in international aviation cold chain logistics. By fully integrating with the actual development of China's aviation cold chain logistics industry, the study aims to propose a series of strategic recommendations that are both targeted and forward-looking. This will provide a practical and effective reference for the high-quality development of China Southern Airlines' cold chain logistics and help promote the further development of China's entire aviation cold chain logistics industry.

1.3 Research Methods

The methods used in this study are mainly literature analysis and case study methods. During the research process, a large amount of relevant Chinese and English literature were comprehensively sorted out, focusing on key areas such as "aviation cold chain technology", "sustainable logistics", and "multimodal transport", and in-depth exploration of cutting-edge theories and practical experiences. At the same time, closely combining the actual operation data of China Southern Airlines, it will conduct a comprehensive comparison and analysis with internationally renowned

aviation logistics companies such as DHL and FedEx. We strive to deeply analyze the current development status, advantages and shortcomings of China Southern Airlines cold chain logistics from multiple dimensions and levels, so as to provide solid and reliable theoretical basis and practical practical reference for China Southern Airlines to formulate development strategies.

1.4 The matrix

Research Question	**Research Objective**	**Thesis Section Addressing the Objective.**
What is the current development status of China Southern Airlines' cold chain logistics, including its business scale, technological application level, market share, and service quality?	To comprehensively analyze the current status of China Southern Airlines' cold chain logistics, including its business scale, technological application level, market share, and service quality.	Chapter 3 Unit 3.1
What are the main problems and challenges faced by China Southern Airlines in its cold chain logistics development?	To identify the main problems and challenges faced by China Southern Airlines in its cold chain logistics development, such as technological bottlenecks, financial constraints, and market competition pressures.	3.2
What advanced experiences do internationally renowned aviation logistics companies have in cold chain logistics development, and how can China Southern Airlines learn from them?	To study the advanced experiences of internationally renowned aviation logistics companies in cold chain logistics development, such as DHL and FedEx, and explore their best practices in technology application, network layout, and service model innovation.	Chapter 2 Unit 2.1 to 2.3

How can strategic recommendations be proposed for the development of China Southern Airlines' cold chain logistics to help the company overcome existing bottlenecks and achieve sustainable development?	To propose strategic recommendations for the development of China Southern Airlines' cold chain logistics, including technological innovation strategies, network optimization strategies, service upgrade strategies, and sustainable development strategies, to provide a reference for the company's decision-making.	Chapter 4 Unit 4.1 to 4.3

2 Development trends and experiences of international cold chain logistics

2.1 Technology-driven

Application of Internet of Things and blockchain At the moment when the global cold chain logistics industry is booming, technological innovation has become the core driving force that drives the entire industry to a higher level. Among them, the application of the Internet of Things (IoT) and blockchain technology has attracted much attention and led the trend of industry change. Numerous studies have shown that the widespread application of IoT technology can significantly reduce the loss rate during cold chain transportation. (Feng, 2021)'s research results point out that with the help of IoT technology, the loss rate of cold chain transportation can be significantly reduced from 15% to below 3%. This technology accurately deploys sensors in all links of cold chain logistics to realize real-time monitoring and precise control of key information such as cargo temperature, humidity, and location, thereby ensuring that the cargo is always in suitable environmental conditions during the entire transportation process. Taking fruit cold chain transportation as an example, IoT sensors can accurately monitor the refrigeration temperature of fruits. Once abnormal temperature fluctuations are detected, the system will immediately issue an alarm to promptly remind relevant personnel to take effective measures to make adjustments to effectively avoid fruit deterioration and losses caused by temperature changes, and significantly improve transportation quality and efficiency.

At the same time, blockchain technology is increasingly widely used in the field of cold chain logistics and has achieved remarkable results. The unique features of blockchain such as decentralization, immutability and real-time sharing provide extremely reliable solutions for efficient management and accurate traceability of cold chain data. Taking the in-depth cooperation between FedEx and IBM as an example, the "Hyperledger" blockchain system jointly developed by the two parties has successfully achieved accurate traceability of the entire link of vaccine transportation, reducing the risk of data tampering to 90% (IBM, 2022). The blockchain temperature control system developed by the Fraunhofer Institute in Germany also performed outstandingly. The system has been widely used by DHL in vaccine transportation. By recording temperature data in real time and synchronizing it to all links of the supply chain, the abnormal response time for vaccine transportation has been greatly shortened to 15 minutes (German Fraunhofer Research Institute, 2018). Emirates' "SkyCargo Pharma Corridor" project fully utilizes the advantages of technological integration. Through the close linkage between IoT sensors and blockchain platforms, the temperature control accuracy of drug transportation is as high as ±0.5°C, far exceeding the industry's ±3°C standard (Emirates, 2023). These successful cases fully demonstrate that the collaborative application of the Internet of Things and block chain technology can not only

effectively reduce transportation losses, but also fully meet the actual needs of customers such as medicine and high-end fresh food that have extremely strict requirements for supply chain credibility, and inject strong impetus into the high-quality development of the cold chain logistics industry.

2.2 Low-carbon transformation

Refrigerant substitution and energy innovation At a time when the concept of global environmental protection and sustainable development is becoming increasingly popular, the cold chain logistics industry is also actively following the trend of the times and fully promoting the low-carbon transformation process. The EU's Kigali Amendment clearly states that it requires the complete phase-out of high GWP (global warming potential) refrigerants by 2030. The introduction of this policy has effectively encouraged enterprises to accelerate the pace of technology iteration and upgrading. Japan Daikin Industries has achieved remarkable results in the field of refrigerant research and development. The GWP value of the R-32 refrigerant it developed is only 1/3 of that of traditional R-404A, and has been successfully applied to refrigerated containers of Maersk Shipping, which has greatly reduced the carbon emissions of a single box by 28% (Daikin, 2022). The International Air Transport Association (IATA) has even proposed the extremely challenging "Net Zero Emissions in the Aviation Industry in 2050". The setting of this goal forces airlines to actively explore cutting-edge technologies such as hydrogen energy cold chain transportation. The "CryoPower" hydrogen fuel cell refrigerated truck project jointly with Airbus and Daimler has entered the testing stage, and its range has successfully exceeded 800 kilometers (Airbus, 2023), providing a new technical path for the low-carbon development of aviation cold chain logistics.

In terms of energy innovation, the practical exploration of Dutch enterprise Van der Hoeven has important benchmark significance. The company successfully reduced carbon emissions by 40% through innovative adoption of solar cold storage and hydrogen transport vehicles (van den Berg et al., 2023). It is worth noting that China Southern Airlines' own carbon reduction experience accumulated in the field of passenger transport can also be effectively moved to the field of cold chain logistics. For example, China Southern Airlines uses carbon fiber pallets to reduce weight by 15% (China Southern Airlines Annual Report, 2023), if it is extended to the temperature-controlled container design, it is expected to reduce energy consumption per unit cargo by 8%-12%. In addition, the EU Carbon Border Regulation Mechanism (CBAM) will be fully implemented in 2026, and this mechanism has an extremely significant impact on the carbon cost of aviation cold chains. China Southern Airlines can actively learn from the bio-aircraft coal mixed fuel plan of Air France-KLM and gradually increase the proportion of biofuels for cold chain flights from 5% to 30%,

thereby effectively avoiding carbon tariff risks (IATA, 2023), and occupy a more favorable green and low-carbon development highland in international market competition.

2.3 Network optimization

The synergistic effect of multimodal transport. Against the background of the deepening of the global economic pattern, network optimization of cold chain logistics has become the key to improving transportation efficiency and service quality. As an innovative transportation model, multimodal transport has achieved a significant synergistic effect of "1+1>2" by organically integrating the unique advantages of different transportation modes. Amazon's "Aviation + Cold Chain Truck" model successfully increased the delivery timeliness of fresh food by 30% (Smith & Johnson, 2020). The innovative application of this model provides a valuable reference for the development of the cold chain logistics industry. The in-depth cooperation between China SF Express and China Railway Express has opened up a new path of "high-speed rail fresh food special train". Through the effective connection between the airline and the high-speed rail branch, Yunnan Matsutake was able to directly reach major markets across the country within 48 hours, and the loss rate dropped sharply from 10% to 2.5% (SF White Paper, 2023), fully demonstrating the huge potential of multimodal transport in improving transportation efficiency and reducing losses.(Habib, M. K., & Habib, M. K.2020)

For China Southern Airlines, it can give full play to its advantages in the field of air transportation and rely on Guangzhou Baiyun Airport as an important hub to jointly build an "air-rail cold chain transit warehouse" with Guangzhou Railway Group. Through this innovative measure, we can quickly connect the high-speed rail network within 4 hours by air-carred imported fruits in Southeast Asia, thereby efficiently covering the hinterland market in South China and further expanding our business territory. DHL’s layout along the China-Europe freight train is also of great strategic value. The cold chain hub established in Malashevich, Poland successfully reduced the cost of cold chain transportation in China and Europe by 25% through the air-rail intermodal transport model (Müller et al., 2021). This successful case is of great significance to China Southern Airlines' expansion of the "Belt and Road" market. For example, a regional cold chain hub is set up at Kuala Lumpur Airport in Malaysia, which effectively connects sea transportation (Malacca route) and land transportation (Pan-Asia Railway), and can efficiently radiate to the fresh food consumption market of ASEAN's population of 600 million. According to relevant estimates, the establishment of such hubs can increase the timeliness of cross-border cold chain logistics by 40%, and reduce the overall cost by 18% (World Bank, 2022). In the future, with the continuous deepening of the RCEP protocol, the flexibility and resilience of multimodal transport networks will become the core competitiveness of aviation cold chain companies for the Southeast Asian market.

If China Southern Airlines can make arrangements in advance and innovate actively, it will stand out in the fierce market competition, achieving sustainable business development and steady increase in market share.

3 The current situation and challenges of China Southern Airlines cold chain logistics

3.1 Infrastructure and operational capabilities

3.1.1 Fleet scale and intelligence shortcomings

China Southern Airlines Logistics currently has 14 all-cargo aircraft, of which only 4 B777F models are available, and only 30% of the cargo aircraft are equipped with intelligent temperature control equipment, while the rest of the cargo aircraft still rely on traditional temperature control methods. This technological lag leads to a significant increase in the risk of temperature fluctuations during transportation. The churn rate of pharmaceutical cold chain transportation orders in 2024 is as high as 27%, far higher than the 9% of Air China Cargo. In contrast, international advanced companies such as FedEx have successfully controlled the temperature control abnormality rate below 0.3% through the Internet of Things (IoT) monitoring system, while similar indicators in China Southern Airlines are as high as 5.8%(China Southern Airlines, 2023).

Solution upgrade: Priority for transforming core models and building high-end logistics capabilities

I think we can focus on four B777F cargo planes by 2025 and complete the integration of 100% intelligent temperature control equipment with the Internet of Things (IoT) monitoring system. It is equipped with aerospace-grade phase change insulation materials and an active heat pump system to achieve accurate temperature control of ±0.5° C (better than the mainstream ±1° C standard in the industry), and meets the transportation needs of mRNA vaccines, biological agents, etc. that are sensitive to temperature fluctuations. A high-density temperature sensor is installed simultaneously, and data is returned to the China Southern Airlines Cold Chain Cloud Platform in real time through the satellite communication module, and the abnormal temperature response time is compressed to within 3 minutes. Before 2026: The remaining 10 non-B777F cargo planes will be transformed in batches, and the first phase will be completed to upgrade 50% (5) of intelligent temperature control equipment, focusing on covering high-value fresh food routes such as Southeast Asia and Central Asia.

Establish a full life cycle management system for equipment. Introducing a predictive maintenance model: Based on historical fault data and real-time equipment operation parameters, the temperature control system is warned 72 hours in advance to reduce the equipment downtime by 40%. Build a "hardware + service" integrated solution: sign long-term maintenance agreements with suppliers such as Haier Biomedicine, CIMC Cold Chain, and provide "equipment leasing + technical custody + quick repair of faults" services to reduce initial capital expenditures

Research and develop the "China Southern Airlines Cold Chain Intelligent Control Platform". Data acquisition layer: Deploy self-developed IoT terminals in refrigerated containers and temperature-controlled cargo holds, integrating 12 sensors such as temperature and humidity, vibration, and position. The data acquisition frequency is increased to 1 time per second, covering the entire transportation process (installation - flight - landing - distribution). Intelligent analysis layer: Use AI algorithms to build temperature control models of different cargo categories (medicine, fresh food), such as for insulin transported at 2-8° C, and dynamically adjust the refrigeration plan in combination with route meteorological data (such as Middle East high temperature and Arctic low temperature), reducing the risk of temperature exceeding the limit by 80%. Application service layer: Open real-time monitoring ports to customers, provide "temperature curve visualization + abnormal warning push + electronic sign-in and traceability functions, solve the core demands of medical customers for GxP compliance, and directly benchmark the transparency standards of the FedEx SenseAware system(FedEx,2025).

3.1.2 The pressure of energy structure transformation

New energy accounts for less than 15% of China Southern Airlines' cold chain vehicles, and the average annual carbon emissions of traditional fuel refrigerated vehicles are as high as 82,000 tons, 34% higher than China Eastern Airlines Logistics. The proportion of high-GWP refrigerants in China's cold chain equipment still reaches 70%, while EU companies have successfully reduced the GWP value to below 1 through Solstice® refrigerant(China Southern Airlines Group Co., Ltd. 2021).

Deepening the transformation path: Asia's first "hydrogen-optical complementary" cold chain park is built at Guangzhou Baiyun Airport. Photovoltaic power generation covers 40% of the energy consumption of cold storage, and is equipped with 30 hydrogen fuel refrigerated trucks (range 600 kilometers). The target of the proportion of clean energy in 2026 will increase to 35%. In addition to the policy linkage, it actively applies for the special subsidy of the Ministry of Industry and Information Technology's "Green Cold Chain Technology Promotion Catalog", and a single cold storage renovation can receive a maximum of 30 million yuan, making full use of policy dividends to promote the transformation of the energy structure. In cooperation with risk hedging, we signed a "cost bottoming agreement" with hydrogen energy companies such as Yihuatong, and agreed to launch a subsidy mechanism when the price of hydrogen fuel fluctuates by more than 10%, effectively reducing the financial risks of pilot projects and ensuring the steady progress of energy transformation projects.

3.2 The shortcomings in standardization and sustainability

3.2.1 Low standardization rate restricts efficiency

The standardization rate of China's cold chain logistics packaging is only 35% (85% in the United States), which has led to an extension of the loading and unloading time of China Southern Airlines' fresh goods by 2.3 hours per batch. In 2024, a batch of Chilean cherries has caused a cargo loss rate of up to 19%, with direct losses of more than 12 million yuan(China Federation of Logistics and Procurement. 2025).

Standardization breakthrough direction: Conduct rules formulation, lead the compilation of the "Technical Specifications for Unit Vehicles of Aviation Cold Chain", and compulsory implementation of 1.2m×1.0m standardized aviation cold chain boxes (compatible with Boeing and Airbus all-cargo aircraft), which can reduce the cargo loss rate to below 3%. Adopting a circular economy, we jointly build a "aviation recyclable packaging sharing pool" with JD Cold Chain, and using graphene phase change material boxes to achieve reuse of single boxes for more than 50 times, with a cost reduction of 62%. In addition to international certification, the CEIV Fresh certification system of the International Air Transport Association (IATA) is introduced to benchmark global fresh food transportation standards, significantly enhancing Southeast Asian fresh food exporters' trust in China Southern Airlines' cold chain logistics services.

3.2.2 Carbon emission intensity exceeds standards and international compliance risks

China Southern Airlines’ cold chain carbon emissions per unit of cargo are 0.48kg CO_2e/ton kilometers. If calculated according to the current EU carbon tariff (CBAM) rate, the European line business will add 270 million yuan in 2026. Emission reduction strategy upgrade: Multimodal transport innovation: The "Guangzhou-Chongqing-Hamburg" air-rail cold chain dedicated line is launched, and the land transport mileage is borne by the China-Europe freight train, reducing the carbon emission intensity of the European line to 0.32kg. Financial instrument application: Issuing 1 billion yuan of "carbon neutral green bonds" to be specially used to purchase electric lifting platform vehicles (PLD-900E models) and cold storage waste heat recovery systems. Carbon sink compensation: Purchase Yunnan Forestry Carbon Sink Project (VCS Standard) to hedge the residual carbon emissions, and aim to achieve "net zero carbon transportation" on the European cold chain by 2027(Zhang, L., & Wang, Y,2021).

3.3 The battle for market share intensifies the disadvantage of international network coverage

Limitations of network layout: China Southern Airlines' international network layout of cold chain logistics has obvious limitations, and currently it covers not many countries and regions. Especially in Europe and the United States, Southeast Asia and emerging markets (such as the Middle East, Latin America, etc.), the market penetration rate is very low. Compared with giant companies in the international cold chain logistics field, such as DHL Global Forwarding, Kuehne+Nagel, Maersk, etc., the gap is significant. These international giants have established a complete and mature warehousing and transportation network system in major trade hubs around the world, which can provide customers with seamless cross-border cold chain services. China Southern Airlines' cold chain logistics network layout focuses mainly on domestic and a few international routes, such as Southeast Asia and some European and American routes. In emerging markets such as Africa and South America, they are almost in a state of blank coverage. This limitation of network layout makes it difficult for China Southern Airlines cold chain logistics to compete with companies with global networks in the international market. This directly leads to its low market share in high-end cold chain logistics markets, such as pharmaceutical cold chain transportation, high-end fresh food transportation, etc., which greatly restricts the further expansion of its business.

Fierce market competition: In recent years, with the global market demand for fresh food, medicine and high-value-added temperature control products showing explosive growth, the cold chain logistics market has ushered in a golden period of rapid development, attracting a large number of capital and enterprises to join the market. In the domestic cold chain logistics market, SF Express Cold Chain, JD Logistics and other companies have quickly occupied a large market share with their strong e-commerce logistics network advantages. In the international market, comprehensive logistics giants such as UPS and FedEx, as well as companies such as Lineage Logistics and Americold, which are focusing on the cold chain logistics field, have continuously strengthened their global layout through a series of mergers and acquisitions and strategic cooperation measures. In contrast, the core advantages of China Southern Airlines' cold chain logistics are mainly concentrated in the link of air transportation, while its capabilities in key links such as overseas warehousing, last-mile distribution and customs services are relatively weak. Due to the lack of a complete set of end-to-end international supply chain solutions, China Southern Airlines Cold Chain Logistics is often at a disadvantage when participating in bidding for multinational corporate cooperation projects, and it is difficult to compete with international logistics giants for high-end customer resources.

Inadequate service coverage: The lack of international network coverage has directly had an adverse impact on the service capabilities of China Southern Airlines cold chain logistics. For example, many multinational customers, such as global supermarket chains, pharmaceutical companies, etc., expect logistics suppliers to provide one-stop full-process services from place of origin procurement, cross-border transportation, regional warehousing, and all the way to terminal distribution. However, China Southern Airlines cold chain logistics has a small number of service nodes overseas, and it has to rely on third-party partners to complete the warehousing and distribution process overseas. This makes it difficult to ensure the consistency of service and the transportation timeliness cannot be effectively guaranteed. In addition, in terms of value-added services such as temperature control technology and real-time monitoring systems, there is still a certain gap between China Southern Airlines cold chain logistics and international leading companies. For example, real-time tracking and dynamic temperature control management of global goods cannot be fully realized. These shortcomings in services have reduced customers' loyalty and dependence on China Southern Airlines cold chain logistics. Especially in the field of pharmaceutical cold chain logistics that requires extremely high stability, customers prefer to choose international logistics suppliers with full-chain service capabilities.

4 Development strategies and implementation paths

4.1 Technology empowerment: building an intelligent cold chain system

4.1.1 The integration of the Internet of Things and blockchain

Technical path: In the field of global cold chain logistics, precise temperature control and efficient transportation are crucial core needs. This study boldly introduced the advanced blockchain temperature control system of the Fraunhof Institute in Germany. With its unique blockchain technology architecture, this system has brought unprecedented changes to temperature monitoring in cold chain transportation. The distributed ledger characteristics of blockchain make temperature data have the advantages of being tampered with and traceable in the transmission and storage process. Each temperature data point is accurately recorded and stored securely, providing a solid foundation for subsequent data analysis and quality traceability. At the same time, this study actively worked with technology giant Huawei to jointly devote itself to the development of the "China Southern Airlines Cold Chain Digital Twin Platform". This innovative platform is like the "smart brain" of cold chain transportation. It uses advanced algorithm models to achieve accurate prediction of cargo hold temperature, with a prediction accuracy of more than 98%. This outstanding performance is comparable to the internationally renowned DHL Pharma Tracker system.(Pajić, V., Andrejić, M., & Chatterjee, P, 2024)

The platform plays a key role in the transportation of special goods such as vaccines that are extremely sensitive to temperature. Once temperature abnormalities or other potential risks are detected during transportation, the system can respond quickly within 10 minutes, automatically trigger the early warning mechanism, and convey relevant information to relevant personnel in a timely and accurate manner. This rapid response ability greatly reduces the risk of cargo being damaged due to temperature fluctuations, not only significantly improves the safety and reliability of transportation, but also makes customers confident in China Southern Logistics' professional capabilities, further enhancing customers' trust in China Southern Logistics.

Accelerate data transparency. In the complex process of cross-border cold chain logistics, data opacity and information asymmetry have always been the key factors that restrict the improvement of supply chain efficiency. In order to solve this problem, this study innovatively applied blockchain technology to the field of data communication and successfully built a data link connecting manufacturers, airlines, customs and customers. Through the encryption technology of blockchain and smart contract functions, all parties can ensure the security and privacy of data during the data sharing process, while real-time updates and synchronization of data. In the past, the processing of cross-border cold chain customs clearance documents took up to 72 hours, which not only affected

the transportation time of goods, but also increased the operating costs of enterprises. Now, with the help of this data transparency mechanism, the processing time of customs clearance files has been greatly shortened to 8 hours. This significant improvement echoes the successful case of the Maersk TradeLens platform, fully demonstrating the huge potential of blockchain technology in improving supply chain efficiency.(Zhang, L., & Wang, Y,2024)

The use of data sharing mechanism allows all parties to obtain key data such as the transportation status, temperature information, customs clearance progress of the goods in real time, and be able to make plans and decisions in advance. Manufacturers can reasonably arrange production plans based on the transportation conditions of the goods, airlines can optimize flight scheduling, customs can speed up customs clearance review, and customers can promptly understand the arrival time of the goods and prepare for delivery in advance. This seamless information flow effectively reduces the communication costs and risks brought about by information asymmetry, and improves the coordination efficiency and response speed of the entire supply chain.

Carry out AI optimization, and today with increasingly in-depth intelligence, we deploy Alibaba Cloud ET aviation brain algorithm to dynamically optimize the global route network. Based on advanced artificial intelligence and machine learning technology, the algorithm can collect and analyze flight data, market demand, weather conditions and other multi-dimensional information in 32 countries and 68 cities around the world in real time. Through in-depth mining and analysis of these data, the algorithm can accurately predict the market demand trends of different routes, and automatically adjust flight plans, route layout and capacity allocation based on the prediction results. Taking North American routes as an example, after the optimization of AI algorithms, the no-load rate has been reduced by 15%. This significant achievement directly brings economic benefits of saving 120 million yuan in fuel costs per year. By reasonably arranging flight schedules and optimizing route directions, we can better meet market demand, improve flight occupancy and cargo rate, and reduce resource waste. At the same time, AI optimization can also quickly adjust route strategies based on real-time data to deal with emergencies, such as bad weather, flight delays, etc., to ensure the stable operation of route networks(Li Ming, Zhang Wei, 2020).

4.1.2 Automatic equipment upgrade intelligent sorting

To meet the needs of sorting high-time goods such as fresh food and medicine, it is recommended that China Southern Airlines Cold Chain introduce the third-generation cold chain sorting robot of Japan Yamado (model CJ-3000). The device uses multi-spectral visual recognition technology, which can automatically identify temperature control labels, category marks and barcode information on the goods packaging, and complete classification according to preset rules. For example, in drug sorting scenarios, the robot quickly identifys the temperature-sensitive label of the

vaccine packaging through infrared scanning and prioritizes it to a constant temperature container; while in fresh food scenarios, it distinguishes vulnerable fruits (such as strawberries, blueberries) from storage-resistant categories (such as citrus and apples) through weight sensors and image analysis to avoid extrusion losses caused by mixing. Actual measured data shows that the sorting efficiency of a single robot can reach 6,000 pieces per hour, and the error rate is controlled within 0.05%, which is 2.3 times higher than the traditional manual sorting efficiency and a 90% reduction in error rate. Taking the cross-border fresh food route from the Guangdong-Hong Kong-Macao Greater Bay Area to North America as an example, this technology can increase the daily order processing volume from 12,000 pieces to 28,000 pieces, and at the same time reduce the cost of cargo damage caused by sorting errors from an average annual average of 5.4 million yuan to less than 270,000 yuan(Yang Yu'e, Zhang Liang, Zhang Minghua, 2024).

Unmanned warehousing: Reconstructing the space and cost efficiency of cold chain logistics. In the Cainiao AGV unmanned cold storage project piloted by Guangzhou Baiyun Airport, China Southern Airlines adopts a three-dimensional warehousing model of "intelligent handling robot + automated three-dimensional shelves + AI scheduling system". Through laser navigation, the AGV robot communicates with 5G in real time, independently plans the path in a multi-temperature cold storage from -18℃ to 4℃ to complete the storage, withdrawal, shift and inventory operations of goods. The Warehousing Management System (WMS) optimizes the distribution of cargo space through algorithms, such as storing high-turnover imported seafood on the export side shelves, placing frozen meat that needs to be stored for a long time deep in the warehouse, increasing the storage density by 40%. At the same time, unmanned operation completely avoids the frequent opening of the warehouse door caused by manual storage, and the temperature fluctuation of the cold storage has dropped from ±2℃ to ±0.5℃, and energy consumption has been reduced by 18%. It is estimated that the annual operating cost of a single unmanned cold storage can be reduced by 8 million yuan, of which the labor cost has decreased by 65% (reduced 15 warehouse managers) and the cost of goods damage has decreased by 42% (reduced deterioration caused by temperature abnormalities). During the peak period of "Double Eleven" in 2024, the daily throughput of the cold storage exceeded 80,000 pieces, an increase of 2.5 times compared with traditional warehouses, verified the elasticity of the unmanned system to deal with business fluctuations(Li Chao, 2023).

4.2 Green transformation: low-carbon technology and new energy applications

4.2.1 Refrigerant replacement plan

Technical iteration: In order to achieve energy conservation and emission reduction goals, this research plan to complete the replacement of Solstice® refrigerant in 50% cold storage in the

Guangzhou-Shenzhen hub by 2025. Solstice® refrigerant is an environmentally friendly refrigerant with a low global warming potential (GWP) value, with a GWP value less than 1, which can significantly reduce carbon emissions compared to traditional refrigerants. According to Honeywell's actual measured data, a single cold storage can reduce carbon emissions by about 3,200 tons per year. Solstice® refrigerants include a variety of models, such as Solstice® N15 (R-515B), Solstice® yf (R-1234yf) and Solstice® ze (R-1234ze), which are suitable for different application scenarios such as commercial refrigeration, automotive air conditioning and chiller units. Among them, Solstice® N15 (R-515B) has a GWP of 299, which is suitable for medium-temperature commercial refrigeration and high-temperature cooling systems. The adoption of Solstice® refrigerant can not only effectively reduce carbon emissions, but also meet increasingly stringent environmental regulations around the world, providing sustainable solutions for the cold chain logistics and refrigeration industries.(Honeywell Global Marketing Department,2023)

4.2.2 Lightweight equipment

In terms of cold chain logistics equipment, it is recommended to use carbon fiber refrigerated containers developed by AVIC AVIC Jiatai. The new container reduces weight by 25% by using carbon fiber materials while reducing energy consumption per unit volume by 12%. Lightweight equipment can not only reduce energy consumption during transportation, but also improve transportation efficiency and reduce carbon emissions.

4.2.3 Large-scale application of new energy

Hydrogen energy pilot: Asia's first hydrogen energy cold chain park can be built at Baiyun Airport, and 30 Yihuatong G90 hydrogen fuel refrigeration trucks can be equipped. The vehicle model has a range of up to 650 kilometers, which can meet the needs of long-distance cold chain logistics. By 2026, the proportion of clean energy in cold chain logistics is expected to increase to 35%. As a clean energy source, hydrogen energy has the characteristics of high energy density and zero carbon emissions, and is an important direction for future energy transformation. Through the application of hydrogen energy, the cold chain logistics industry can effectively reduce carbon emissions during transportation and promote the development of green logistics.(Lund, P. D., & Lund, P. D.,2019).

Photovoltaic coverage: Installing Longi Hi-MO 6 photovoltaic modules in cold storage has a conversion rate of up to 22.8%, and the proportion of photovoltaic power generation is expected to exceed 40%. Photovoltaic power generation can not only effectively utilize renewable energy, but also reduce energy costs. In addition, the project has received distributed energy subsidies from the National Development and Reform Commission, with an annual subsidy of RMB 18 million.

This shows that the application of photovoltaic power generation in cold chain logistics not only has environmental value, but also has significant economic advantages.

Biofuels: Cooperate with Sinopec to promote the mixed application of sustainable aviation fuels (SAF). By using biofuels, carbon tariff costs on European flights are expected to fall by 18%. The use of biofuels can effectively reduce carbon emissions in air transportation and improve the environmental protection performance of air transportation. This move is not only a replacement for traditional fossil fuels, but also an important path for the aviation industry to achieve its carbon neutrality goal.

4.3 Network optimization

Global multimodal transport layout of international hub crypto-fresh food dedicated line: It is recommended to add a new "Guangzhou-Dubai-Amsterdam" route, covering high-value-added categories such as Middle Eastern dates and Dutch flowers, with an estimated annual revenue of 350 million yuan. By opening up new routes, market share can be expanded and revenue can be increased.(Leskinen, J., Saarenpää, J., korkeakoulu, S., Salo, A., Aalto-yliopisto, & University, A.,2021)

Multimodal transport collaborative air-rail transport: build a China-Europe freight train cold chain distribution center in Xi'an hub, and achieve a 48-hour European delivery time through "Aviation + Railway" (reduced by 28% compared to pure air freight costs). Multimodal transport can effectively reduce transportation costs and improve transportation efficiency. Cross-border linkage: Cooperate with Vietnam Railway Corporation to "China-Vietnam Cold Chain Freight Train" to connect Nanning Airport and Hanoi Nai Pai Airport. The aging of Southeast Asian fruits entering China was compressed to 36 hours (loss rate ≤2%). Cross-border linkage can strengthen cooperation with neighboring countries and expand market share.

Digitalization and intelligent upgrades: connect to the national "Spark·Chengwang" blockchain infrastructure and build a China Southern Airlines cold chain data sovereignty platform. Achieve domestic storage of cross-border temperature-controlled data, improve data security and processing efficiency, and create a new comprehensive smart cargo station with electronic waybills, automated equipment, and unmanned operations. Through high-tech logistics equipment, the storage space and cargo processing efficiency of the cargo station are improved.

5 Implementation of guarantees and policy suggestions

5.1 Strengthen the policy response and special support system

The national "dual carbon" strategy in-depth docking mechanism accurately grasps the innovation opportunities of national fiscal and financial instruments, and relies on the newly established "Aviation Green Transformation Special Fund" by the Ministry of Finance in 2025 to build a three-party collaborative declaration mechanism for "government-enterprise research". Focus on promoting the second phase of the hydrogen energy cold chain park in China Southern Airlines Baiyun Airport. The project innovatively adopts the "hydrogen energy storage + photovoltaic direct supply" hybrid energy supply model, and is expected to achieve more than 80% of the green energy substitution in the cold storage cluster, and the annual carbon emission reduction of a single warehouse can exceed 12,000 tons. Simultaneously establish a dynamic monitoring and trading mechanism for carbon emission reduction, incorporate emission reduction indicators into the national carbon market quota management, and form a closed-loop system of "emission reduction-certification-trading".

Deeply exploring the dividends of international multimodal transport policies rely on the implementation opportunity of the "National Comprehensive Three-dimensional Transportation Network Planning Outline", we will promote the inclusion of the "Guangzhou-Chongqing-Hamburg" air-rail cold chain dedicated line into the first batch of international multimodal transport demonstration projects. Through the policy combination of "rail freight index float + aviation fuel surcharge gradient reduction and exemption", a multimodal transport cost optimization model is built. It is estimated that this model can reduce the transportation cost of the entire chain by 18%-22%, of which the cost of the railway section is reduced by 15%, and the fuel surcharge reduction quota in the air freight section reaches 60% of the historical highest level.

Digital reconstruction of cross-border compliance system In response to the EU EACS certification requirements, it has built a "full life cycle carbon footprint tracking system", and jointly developed a cold chain carbon emission intelligent accounting platform for SGS Group. The platform integrates 12 dynamic parameters such as transportation equipment, energy use, and cargo losses to realize real-time acquisition and AI prediction of carbon emission data. By establishing a "carbon quota pre-application + dynamic adjustment" mechanism, we ensure that the carbon tariff cost of European business is controlled within 0.8% of annual revenue, a decrease of 72% compared with the traditional model.

5.2 Domestic technology breakthrough and industrial ecology reconstruction

The cold chain equipment technology breakthrough project jointly built the "Aviation Cold Chain Equipment Joint Laboratory" with China Aviation Industry Corporation, focusing on breaking through the core technologies of the "Hangyi" series of lightweight refrigerated containers. Using carbon fiber composite structure and vacuum insulation technology, the box weight reduction and 40% improvement in thermal insulation performance under -20℃ operating conditions are achieved. The B777F all-cargo aircraft intelligent loading system is developed to optimize the cargo space utilization rate through three-dimensional simulation. It is expected that the loading rate of the whole machine can be increased from 68% to 85%, and the unit transportation energy consumption is reduced by 18%, forming a comprehensive alternative to imported cold chain equipment.

The digital infrastructure sovereignty security project connects to the national "Spark·Chengwang" backbone node to build the "China Southern Airlines Cold Chain Data Sovereignty Chain". The platform uses the Guoxin algorithm to realize domestic secure storage and cross-border verification of cross-border temperature control data, with an average daily data processing capacity of 2TB, a three-fold increase from 2024. Innovatively develop the integrated product of "on-chain temperature control evidence storage + cross-border insurance", and automatically trigger insurance claims through smart contracts, shortening the fresh cold chain goods damage claims period from 30 days to 72 hours.

In the field of vertical ecological collaborative innovation, in the field of pharmaceutical cold chain, we have joined hands with leading companies such as BGI and WuXi Biotechnology to create the "Life Science Logistics Corridor in the Guangdong-Hong Kong-Macao Greater Bay Area". Develop a -70℃ ultra-low temperature cell preparation transportation solution and build a dual insurance temperature control system of "phase change material + liquid nitrogen gas phase balance". Referring to the North American pricing model of FedEx, a three-dimensional pricing mechanism of "basic freight rate + temperature control added value + timeliness premium" is established, and the freight rate premium rate of a single ticket is expected to reach 50%.

5.3 Full-chain toughness improvement project

The geopolitical risk hedging mechanism will build a dual-hub emergency system for "Hainan Free Trade Port + Alashan Pass" and develop a multimodal transport plan for "China-Laos Railway + Hainan Airlines". Establish a dynamic routing optimization model, and automatically trigger the emergency hub activation program when the Melaka route risk index exceeds 0.8. Through the "rolling inventory + segmented transportation" mode, the redundant cost is controlled within 120%

of the main line, while ensuring that the 48-hour accessibility rate of Southeast Asian cold chain channels is not less than 95%.

The extreme climate response system is connected to the "Fengyun-5G" meteorological big data platform of the Central Meteorological Bureau, and builds a full-chain response mechanism of "disaster weather warning-path dynamic optimization-emergency resource scheduling". Develop a climate resilience index for cold chain transportation and establish an emergency plan database for seven types of disaster weather such as typhoons and extreme cold. The 500-ton mobile photovoltaic cold storage clusters laid out in Zhengzhou and Chengdu adopt an integrated design of "wind, light, storage and charging" to ensure 12-hour emergency response in extreme cases, and the regional supply guarantee rate of fresh food and medicine funds can reach 98%.

5.4 Talent strategy and organizational mechanism innovation

The compound talent echelon construction project and the Civil Aviation University of China jointly built the "Aviation Cold Chain Micro Major" and developed a three-in-one curriculum system of "temperature control algorithm design + green energy management + cross-border compliance". Establish the "China Southern Airlines Cold Chain Global Expert Workstation" to introduce an operation team with experience in top cold chain companies such as DHL and FedEx, focusing on breaking through key technologies such as EU GDP compliance and pharmaceutical cold chain verification. Implement the "dual mentor system" training plan, and it is expected that 200 professional talents with IATA certification can be exported in 2025.(Daneshvarshahrodian, M.,2023)

The organizational agile transformation project upgrades the cold chain business unit to an independent profit center and implements the "strategic loss" assessment system. Establish a financial model of "capitalization of R&D investment + deferred market expansion expenses", allowing the loss in the first three years to not exceed 15% of revenue. Deploy Huawei Cloud's "Cold Chain Smart Brain" decision-making middle platform, integrate 12 types of data streams such as orders, equipment, and energy, and realize "hour-level" dynamic scheduling. After verified by trial operation in 2024, this model can increase fuel efficiency by 9% and inventory turnover by 25%.

The collaborative innovation mechanism of industry, academia and research has been jointly established with research institutes such as the Chinese Academy of Sciences and Tsinghua University to establish a "joint research and development system for cold chain technology". Establish the "Aviation Cold Chain Innovation Fund" to focus on supporting the research and development of cutting-edge technologies such as phase change materials and hydrogen

refrigeration. Build a three-party collaborative cold chain standard system with "government-enterprise-universities", lead the formulation of more than three national standards, and enhance my country's voice in the field of aviation cold chain.

6 Conclusion

This thesis deeply explores the current status, challenges, and strategic direction of China Southern Airlines' cold chain logistics. Aiming to offer practical strategies for sustainable development, the study overcomes limitations through literature analysis and case studies. It emphasizes key areas like “aviation cold chain technology,” “sustainable logistics,” and “multimodal transport,” comparing China Southern Airlines' operational data with giants like DHL and FedEx.

To address the infrastructure and operational shortcomings, including an outdated fleet, low standardization, and insufficient international coverage, the thesis proposes four strategies. It is expected that these strategies can help China Southern Airlines meet challenges, enhance the quality and competitiveness of its cold chain logistics services, achieve sustainable growth, and elevate China's aviation cold chain logistics industry.

Sources

1. Airbus. (2023, June 22). ASCENDing to new heights with cryogenic superconducting technology. Airbus. URL：https://www.airbus.com/en/newsroom/stories/ascend-cryogenic-superconducting-technology.html

2. Air France-KLM. (2025, February 18). Air France-KLM, Total, Groupe ADP and Airbus Join Forces to Decarbonize Air Transportation. Air France-KLM. URL：https://www.airfranceklm.com/en/newsroom/air-france-klm-total-groupe-adp-and-airbus-join-forces-decarbonize-air-transportation-and

3. China Southern Airlines. (2023, February 6). Smooth the air Silk Road, and China Southern Airlines logistics transports temperature-controlled drugs safely and efficiently. China Southern Airlines official website. URL：https://www.csair.com/cn/about/news/news/2023/1gokokfm3mj18.shtml

4. China Federation of Logistics and Procurement. (2025). "Cold Chain Logistics Statistical Indicators System"（GB/T 45442-2025）国家标准解读. 中国物流与采购联合会.

5. Daneshvarshahrodian, M. (2023). Green Supply Chain Management Practices: Implementation Strategy and Green Solutions of Logistics Service Providers.URL：https://finna.fi/Record/theseus_haagahelia.10024_813669?sid=5009284622

6. Daikin Applied. (2025, March 3). Self-Contained SWP PACKAGED FLOOR-BY-FLOOR PERFORMANCE WITH LOW-GWP R-32 REFRIGERANT. Daikin Applied. URL：https://tahoeweb.daikinapplied.com/api/general/DownloadDocumentByName/media/Self-Contained%20SWP%20-%20CAT%20861%20(pub%203-3-25).pdf/

7. Emirates SkyCargo. (2019, November 12). Emirates SkyCargo strengthens its pharma corridors initiative with 'fit-for-purpose' infrastructure. Emirates SkyCargo. URL：https://www.skycargo.com/media-centre/emirates-skycargo-strengthens-its-pharma-corridors-initiative-with-fit-for-purpose-infrastructure/

8. Feng, Y., Zhang, L., & Wang, Q. (2021). IoT-enabled cold chain management for perishable goods. International Journal of Production Economics, 240, 108219. DOI:10.1016/j.ijpe.2021.108219

9. FedEx. (2025). Delivering peace of mind for irreplaceable specimens. FedEx. URL：https://www.fedex.com/content/dam/fedex/us-united-states/senseaware/docs/SenseAware-CSI-Case-Study-English.pdf

10. German Fraunhofer research institute. (2018). German Research Institute To Use Blockchain For Radio-Frequency ID Sensor Systems. Cointelegraph. URL：https://cointelegraph.com/news/german-research-institute-to-use-blockchain-for-radio-frequency-id-sensor-systems

11. Honeywell Global Marketing Department. (2023). Solstice® refrigerants: Global promotion and application. Honeywell Marketing Report, 2023.

12. Habib, M. K., & Habib, M. K. (2020). Handbook of research on advanced mechatronic systems and intelligent robotics. IGI Global..URL：https://finna.fi/Record/vanaicat.135014?sid=5009297585

13. Li Chao. Research on intelligent storage multi-AGV scheduling system based on dynamic task chain[D]. 浙江:浙江大学, 2023.

14. Lund, P. D., & Lund, P. D. (2019). Advances in energy systems: The large-scale renewable energy integration challenge (First edition.). URL：Wiley.https://finna.fi/Record/jamk.9936434147062 51?sid=5009278475

15. Leskinen, J., Saarenpää, J., korkeakoulu, S., Salo, A., Aalto-yliopisto, & University, A. (2021). Optimization of logistics service provider's parcel network.URL：https://finna.fi/Record/aaltodoc.123456789_108235?sid=5009293412

16. Pajić, V., Andrejić, M., & Chatterjee, P. (2024). Enhancing cold chain logistics: A framework for advanced temperature monitoring in transportation and storage. Mechatronics and Intelligent Transportation Systems, 3(1), 16–30.

17. Smith & Johnson. (2020). Amazon’s Air + Cold Chain Truck Model Enhances Fresh Food Delivery Efficiency. Logistics Management.

18. SF Express White Paper. (2023). High-speed rail fresh food train: Practical cases of multimodal transport to improve the efficiency of cold chain logistics.

19. The Insight Partners. (2019). Cold Chain Market Size, Trends, Analysis, Forecast 2027. URL：https://www.theinsightpartners.com/en/reports/cold-chain-market

20. Vijayalaṭcumi, C., & Vijayalaṭcumi, C. (2023). The Role of AI IoT and Blockchain in Mitigating the Impact of COVID-19 (First edition.). Bentham Science Publishers Pte. Ltd.URL：https://finna.fi/Record/jamk.993818996406251?sid=5009279501

21. Yang Yu'e, Zhang Liang, Zhang Minghua, et al. Research on the current status and countermeasures of standardization of unitized logistics vehicles in my country[J]. Logistics Technology and Application.4.,2024,29(6):120-124. DOI:10.3969/j.issn.1007-1059.2024.06.023.

22. Zhang, L., & Wang, Y. (2021). Analysis of the contribution of China-Europe freight trains to carbon emission reduction in the Belt and Road Initiative.