Selection of Air Carrier for AD Company Vaccine Based on AHP

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Abstract

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The global distribution of the New Crown epidemic dictates that the successful development of the vaccine will be followed by cross-border delivery and immunization around the world. In view of the specificity of temperature requirements of vaccines and the complexity of delivery, it is important to explore how to select air carriers for New Crown vaccines. This paper takes AD's vaccine cold chain logistics air carrier as the research object. The paper analyzes the background of China's vaccine cold chain logistics industry and the current situation of AD's vaccine logistics, identifies the problems of AD's vaccine cold chain logistics, and proposes three air carriers, namely Air China Cargo, Eastern Air Cargo and Southern Air Cargo, and uses AHP and interview methods to carry out indexes for the three air carriers The analysis and weight calculation of the three air carriers were conducted by using AHP and interview method. Through comprehensive evaluation and analysis of air carriers, this paper finally selects Southern Air Cargo as the optimal air carrier for AD's vaccines, which provides reference value for related industries to select more suitable air carriers, thus ensuring smooth operation of vaccine logistics and providing strong support for global vaccination.

Key words
Vaccine logistics; AHP; air carrier

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1 Introduction

In this paper, this chapter will delve into the core issues and challenges of this research field from the perspective of the background and research objectives of the topic. By systematically analyzing existing research achievements and shortcomings, this thesis aims to propose clear research questions and provide theoretical basis and practical guidance for solving these problems. In the introduction section, an overview of the overall framework and ideas of the paper will be provided, providing readers with a clear direction to better understand and grasp the core viewpoints and contributions of the paper.

1.1 Background of the topic selection

Air transport of new crown vaccines is one of the important measures in the global response to the new crown epidemic. In response to the special transportation requirements of the new crown vaccine, major airlines around the world are actively adjusting their capacity and improving transportation capacity to ensure that vaccines can be safely and timely transported to various vaccination sites around the world. (Wu Xuanyu 2021.)

At present, the main background of air transportation of new crown vaccines includes the following aspects:

High demand for vaccines: The global demand for COVID vaccines is so high that governments and organizations are actively sourcing and distributing vaccines. This requires significant air transport capacity to support the transportation and distribution of vaccines.

Strict transportation requirements: The transportation requirements of the new crown vaccine are very strict, and it needs to be transported under specific temperature and humidity conditions to ensure the quality and effectiveness of the vaccine. This places very high demands on air transport.

High transport safety: The new crown vaccine is a high-value item and has very high requirements for transportation safety. Airlines are stepping up cargo safety measures to ensure the safety of vaccines in transit.

Close international cooperation: The production and distribution of COVID-19 vaccines requires global cooperation, and close coordination and cooperation between governments and organizations is needed to ensure that vaccines can be smoothly transported to countries and regions.

In general, air transportation of new crown vaccines is one of the important measures to respond to the new crown epidemic on a global scale, which requires close cooperation and coordination

between governments, organizations and airlines to ensure that vaccines can be safely and timely distributed to various vaccination sites.

1.2 Research objectives

This thesis will evaluate and select the feasibility and effectiveness of AD vaccine air carriers based on the AHP methodology, and select the most suitable carrier for AD vaccine air transportation to optimize the efficiency and quality of vaccine transportation. The research methods and steps are based on the AHP method, including the determination of evaluation criteria and sub-criteria, weight allocation, establishment of hierarchical models, pair-by-pair comparison, calculation of weights and comprehensive evaluation. The findings are an analysis and interpretation of the scores and rankings of individual vaccine air carriers under different criteria and sub-criteria, as well as the final assessment results. This paper will provide reasonable interpretation and inference of the evaluation results, and propose suggestions and improvements for future research and practice.

1.3 Research questions

What are the factors and indicators that affect the selection of vaccine air carriers? What to do after selecting indicators?

Identify decision factors: First, you need to identify the main decision factors that influence the choice of air carriers for vaccines. These factors include cost, time, safety, quality of service, carrier capacity, etc. Through surveys and expert interviews, you can find out what you pay the most attention to in the actual needs of your business.

Build a selection model: After determining the decision-making factors, you need to build a selection model that works. In this paper, the analytic hierarchy method (AHP) is used to construct a vaccine air carrier selection model. With this model, complex decision-making problems can be broken down into cascading subsystem problems to better evaluate and compare different carriers.

Where does the paper data come from? How to process data?

Data collection and processing: In order to use the AHP model for empirical analysis, relevant data needs to be collected and processed. In this paper, three air carriers with high market share were selected as the evaluation objects. Then, each decision factor is scored to build a judgment matrix. This process can be carried out with the help of expert scoring.

How to choose a solution?

Weight calculation and scheme selection: AHP is used to calculate the weight vector of each decision-making factor. The comprehensive score of each scheme is calculated according to the weight vector, and the optimal air carrier is finally selected.

What is the purpose of the calculation results?

Result analysis and application: Detailed analysis of empirical analysis results to verify the validity of the model. Based on the results of the analysis, AD was advised on the selection of suitable vaccine air carriers.

Inspiration for other enterprises: The methods and conclusions of this study not only have guiding significance for AD company, but also provide reference for other enterprises to make decisions on similar issues.

1.4 Structure

This thesis first clarifies the research background, outlines the basic theory and research status of cold chain logistics and third-party logistics. Secondly, a field research is conducted, the situation of AD company is conducted and interviewed, the company's data is obtained, and the relevant logistics evaluation index system is established. Complete the design and collection of questionnaires based on the construction system, then scoring the AD company's vaccine logistics status, and finally make decisions and suggestions to optimize the strategy and provide the optimal solution for AD companies. for reference. The specific structure of this thesis is arranged as follows:

The first part mainly introduces the topic selection background and research goals of papers, and explains the research content and structural arrangements of this thesis, and summarizes the research methods and main innovation of the entire papers.

The second part conducts the theoretical framework and literature review of the thesis research, which focuses on the basic theory of third-party logistics and the literature of cold chain logistics research to lay a solid foundation for the theoretical basis of the theory of the whole papers.

The third part introduces the research method of this thesis-hierarchical analysis method, including the literature review, specific implementation steps of the layer analysis method, and the data collection and data analysis methods of this thesis.

The fourth part transitions to the specific study of corporate cases. Chapter IV chapter first introduces the industry background of the AD company's vaccine cold chain logistics operation, and objectively analyzes the status of AD's vaccine cold chain logistics operation. Then it introduced the profile of AD Company, introduced the supply and circulation channels during the

specific operation business, and analyzed the problems and reasons of the AD company's vaccine cold chain logistics.

The fifth part first selected a suitable indicator and constructed the evaluation index system. Secondly, the AHP was used to calculate the scoring data obtained and sorted the weight of each indicator in the calculation result.

The sixth part is based on the results of the AD company vaccine and aviation carrier to select the optimal solution, and refer to the opinions of expert interviews with AD companies and other related industry companies to propose vaccine transportation suggestions and aviation carrier selection suggestions.

The seventh part is concluded. Summarized the research on this thesis and pointed out the shortcomings of this thesis.

Table 1 contains a model of the overlay matrix, the investigative questions of which are used to solve the research problem: How to Choose the Optimal Vaccine Air Carrier Plan for AD Company?

Table 1. Overlay matrix

Investigative questions	Theoretical framework (chapter)	Results (chapter)
What are the factors and indicators that affect the selection of vaccine air carriers?	2	5.1
What to do after selecting indicators?	5.2	5.2
Where does the paper data come from?	3.3	5, 6
How to process data?	3.4	6
How to choose a solution?	5.2	6
What is the purpose of the calculation results?	6	7

2 Theoretical framework

In the literature review section of Chapter 2, this chapter will comprehensively review and analyze research literature in relevant fields, in order to provide theoretical basis and support for the research of this thesis. This chapter will discuss third-party logistics, cold chain logistics, IATA medical vaccine air transport security system and other aspects. By summarizing and summarizing existing literature, we can identify the current research status, identify research deficiencies, and lay a solid theoretical foundation for subsequent empirical analysis.The structural diagram of this chapter is shown in Figure 1.

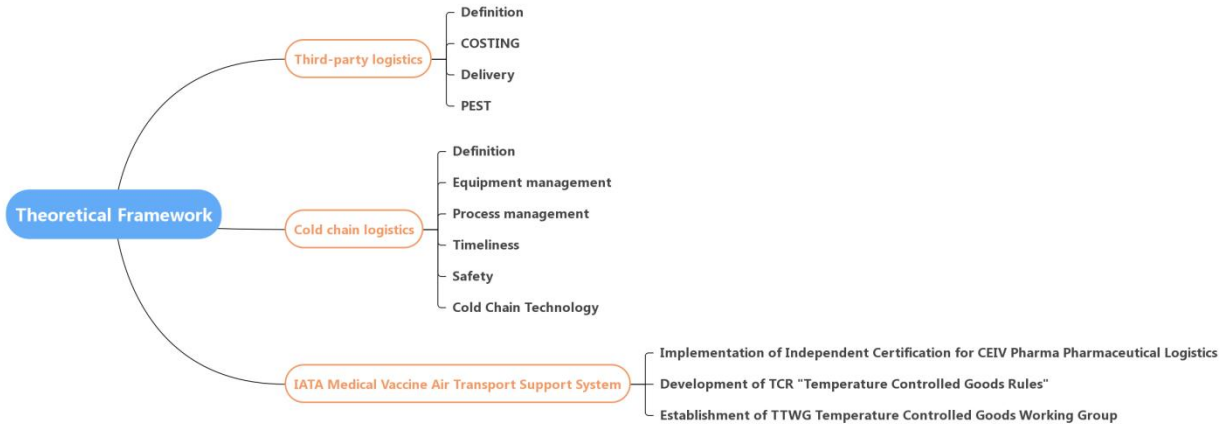

Figure 1. Theoretical framework diagram

2.1 Third-party logistics

The term "third-party logistics" (TPL or 3PL) began to prevail in the late 80s of the 20th centuries, first proposed in a customer service survey conducted by the U.S. Logistics Regulatory Commission in 1988, and this new thinking was incorporated into customer service functions, described as "logistics service providers". (Ren Xiangyi & Zou Xiao 2022, 132-133.) With the intensification of market competition and the pursuit of efficiency, the social division of labor between organizations is becoming more and more detailed. In order to improve their core competitiveness and reduce costs, enterprises are increasingly willing to subcontract unfamiliar businesses to other social organizations. Because of this, some enterprises engaged in logistics-related transportation, warehousing, freight forwarding and other enterprises with better conditions began to expand their traditional business, entered the logistics system, and gradually grew into enterprises that can provide some or all logistics services.

Li Fei (2022, 183) found in his research that the overall cost of China's logistics industry is too high and inefficient, and studied the problems of logistics cost control from the perspective of supply

chain, which helped AD companies pay more attention to the problem of controlling costs when choosing a carrier for vaccines. Ren Xiangyi (2022, 132-133.) and others proposed that third-party logistics services have many advantages in logistics services, which will surely become the growth point of the national economy, which will help AD companies pay more attention to the third-party logistics service capabilities of carriers when selecting vaccine air carriers, so as to optimize the vaccine transportation process; Pan Zhengtong (2022, 105-106) takes Company N as an example to find and solve various problems encountered in the process of receiving and distributing goods in third-party logistics, which provides reference significance for Company A and D to select a carrier in this paper. Liang Ying (2019) analyzed the development trend of third-party pharmaceutical logistics, taking enterprise A as an example, and put forward feasible suggestions for the transformation and development of third-party pharmaceutical logistics enterprises in China's small and medium-sized pharmaceutical wholesale enterprises, which will help AD companies to consider various factors more comprehensively when choosing air carriers, thereby improving the decision-making effect; Zheng Yuxiang and Shen Chiai (2019, 16-17) also analyzed the development of third-party pharmaceutical cold chain logistics in China, and based on PEST environmental analysis, proposed that the development trend of pharmaceutical cold chain in the future needs professional support, which is conducive to the comprehensive analysis of the current situation of AD company in this paper.

In conclusion, the literature review of third-party logistics has an important guiding role in the selection and management of vaccine air carriers of AD, which is helpful for AD companies to achieve more efficient and high-quality services in the field of vaccine transportation.

2.2 Cold chain logistics

2.2.1 The concept of cold chain logistics

Cold chain logistics refers to the control of the temperature and humidity of products through a series of special measures and equipment in the whole process of product production, storage, transportation, sales and so on, so as to ensure the quality and safety of products. In layman's terms, cold chain logistics is to use a series of special measures and methods to transport products that need to be transported in a low temperature environment to their destinations, while ensuring their quality and safety.

Cold chain logistics is mainly used in products that need to be transported in a low temperature environment, including fresh food, medicines, vaccines, cosmetics, flowers, etc. During the transportation of these products, the temperature and humidity need to be strictly controlled to avoid rot, deterioration, failure and other situations. Therefore, cold chain logistics not only requires

special equipment and means of transportation, but also requires certain technical and operational specifications.

The core elements of cold chain logistics include temperature-controlled equipment, transportation, temperature-controlled packaging, logistics management systems and professional talents. Among them, temperature control equipment and transportation tools can realize transportation and storage in low temperature environments; Temperature-controlled packaging can protect and isolate the product to ensure its temperature and humidity during transportation; The logistics management system can realize the monitoring and scheduling of the entire cold chain logistics process; Professional talents can ensure the professionalism and reliability of operation and management in the cold chain logistics process.

In general, cold chain logistics is a special form of logistics designed for products that need to be transported in a low temperature environment, and its core is to ensure the quality and safety of products during transportation by strictly controlling temperature and humidity.

2.2.2 A review of research on cold chain logistics

This review of cold chain logistics is mainly divided into two aspects, which elaborate on cold chain logistics management and cold chain technology.

In terms of cold chain logistics management, Di Hongxi, Wei Jiuchang, Zhang Ya and Lu Yiming (2022, 54-60) identified and responded to the risks in the cold chain of vaccines under major epidemics, indicating that it is necessary to clarify the prevention and control priorities and formulate targeted control measures, such as strengthening personnel training, rationally planning the path and location of vaccination sites, and increasing the inspection and update of facilities and equipment, etc., and their research results can provide a reference for the efficient and safe operation of vaccine cold chain logistics. Through the study of the medical supply chain, foreign scholars Skowron-Grabowska, B., Wincewicz-Bosy, M., Dymyt, M., Sadowski, A., Dymyt, T., & Wąsowska, K. (2022) found that the key factor in its reliability is the coordination and comprehensive cooperation of the institutions involved in the transportation process; Liu Lingling (2022, 120-123) through the study of a company's third-party pharmaceutical logistics customer service management, the company in the case made a number of innovations in logistics customer service management from the perspective of improving logistics service level and customer satisfaction, and built a set of logistics customer service management system, which greatly improved efficiency and management level; Luo Ji and Xing Wenjie (2021, 162-164) found the current problems of lack of vaccine cold chain talents, low market openness, and insufficient emergency response capabilities, and then discussed the innovative management strategies of

China's vaccine cold chain logistics in the epidemic era, and made suggestions for improving the professionalism and service level of vaccine cold chain logistics in China. Du Xinyi (2021) proposed how to improve the timeliness and safety of vaccine transportation, and put forward the viewpoint of optimizing the structure, equipment, technology and personnel of the entire vaccine cold chain supply chain, using Internet of Things technology, blockchain technology and social logistics enterprises. Jiang Lan and Huang Xianjun (2018, 110-111) analyzed the development status and existing problems of the vaccine cold chain logistics industry, and proposed that drugs are an important industry related to the national economy and the development of the entire society, and at present, with the continuous improvement and development of science and technology and industry, the development of pharmaceuticals has also been promoted, and some special drugs are inseparable from the development of cold chain logistics.

In terms of cold chain technology, Tian Maode (2022) uses mathematical methods to systematically use blockchain technology to effectively improve the safety and efficiency of vaccine cold chain traceability system, and also has good reference significance for other cold chain logistics industries. Tian Jizhao, Wang Shihui, Guo Ying, Zhu Zhijie&Yang Wenjie (2020) designed the cold chain packaging system through experiments to reduce the cost of cold chain packaging, but also shorten the operation time of vaccine packaging, greatly improve the operational efficiency of cold chain logistics and improve the safety of vaccine cold chain. Ng, C. Z. , Lean, Y. L. , Husain, K. , Kotra, V. , & Long, C. M. . (2019, 10) experimentally studied the cold chain temperature maintenance of vaccines and other biological products supplied by pharmaceutical wholesalers, and found that the packaging method, container material and size have ADirect impact on the cold chain insulation effect, and polystyrene foam boxes, polyethylene lined and polypropylene insulated refrigerators, and refrigerator bags with an appropriate number of ice packs can be effectively used for the transportation of vaccines within their respective transportation periods.

The literature review of cold chain logistics provides AD with background knowledge about the cold chain logistics industry, helping them understand the importance of cold chain logistics in vaccine transportation, as well as the industry status, challenges and development trends. This will help AD companies pay more attention to the carrier's strength and experience in cold chain logistics when selecting an air carrier for vaccines. Through the above literature review, the information on the current situation, key factors, technological innovation, risk management, cooperation strategy, sustainable development, and policies and regulations of the cold chain logistics industry is analyzed, which will help AD companies achieve more efficient, safe and sustainable services in the field of vaccine transportation.

In conclusion, the literature review of cold chain logistics has an important guiding effect on the selection of vaccine air carriers in AD.

2.3 International Air Transport Association (IATA) Pharmaceutical Vaccine Air Transport Guarantee System

Due to the impact of the world pandemic, there is a serious shortage of air cargo capacity. As early as September 2020, IATA (International Air Transport Association), as a professional body for global air transport, called on countries to prepare for the shipment of new crown vaccines, and urged governments and related industry enterprises to plan for the transportation of new crown virus vaccines in advance before the successful development of new crown virus vaccines. In fact, IATA has long been committed to regulating and guiding air transport, and has previously established an air transport guarantee system for medicines and vaccines, as shown in Figure 1.

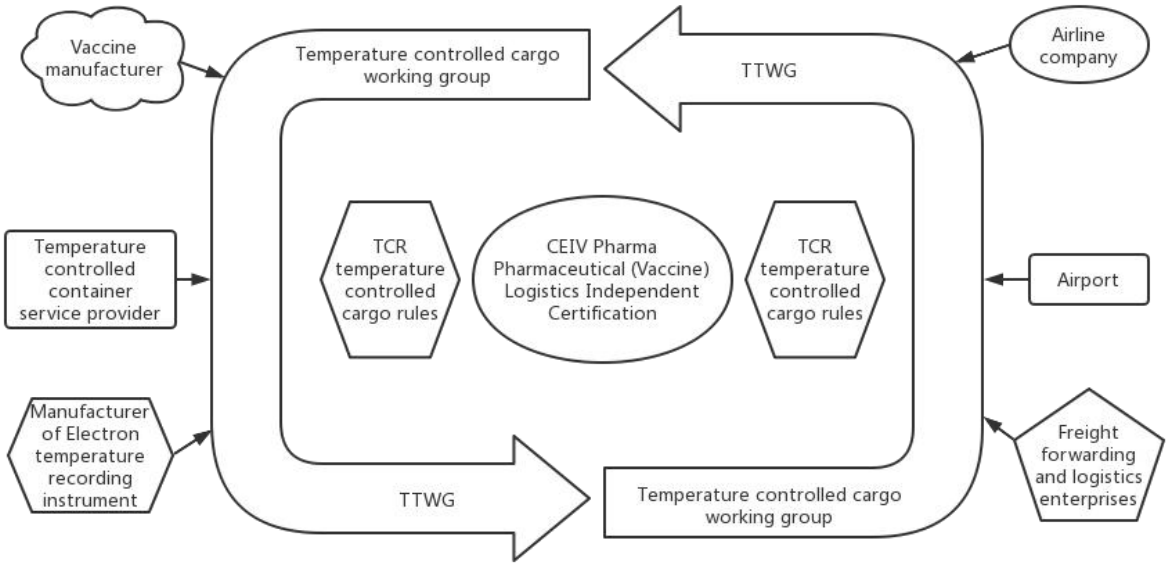

Figure 2. IATA air transport guarantee system for pharmaceutical vaccines

2.3.1 CEIV Pharma (2021) implementation of independent certification for pharmaceutical logistics

In order to review and identify the air transport guarantee qualification of the applicant enterprises from a professional level, IATA cooperated with national pharmaceutical regulatory departments and airlines to build the CEIV Pharma certification system in accordance with the rules and standards of international air transport of pharmaceutical vaccines, integrating and replacing the World Health Organization's Good Manufacturing Practices - GMP and the US Pharmacopoeia Standards - Pharmacopeia Standards", TCR, GDP and other relevant rules and standards,

thereby unifying global standards, establishing and implementing independent certification of pharmaceutical logistics, and providing professional guarantee for the qualification certification of new crown vaccine air logistics enterprises in advance.

2.3.2 TCR (2021) Formulation of the Temperature-Controlled Cargo Rule

Due to the strict requirements for temperature control and transportation time of pharmaceutical vaccines, in order to provide guidance for efficient and safe air transportation of such products, IATA has formulated the Temperature Control Regulations (TCR), which is updated once a year, mainly covering government regulations, carrier rules, drug classification and its temperature characteristics, packaging requirements, Document production, cargo receipt, warehousing and loading, electronic information recording, etc. TCR provides authoritative norms and standards for the current cross-border logistics of new crown vaccines to effectively ensure temperature control and transportation safety.

2.3.3 TTWG (2021) Establishment of the Working Group on Temperature-Controlled Goods

In order to ensure the coordinated development of air transport activities for pharmaceutical vaccines, IATA has established a 25-member Time and Temperature Working Group (TTWG), involving upstream and downstream enterprises and organizations throughout the air transport chain, including pharmaceutical vaccine manufacturers (such as DuPont), Temperature-controlled container service providers (e.g. Envirotainer), freight forwarding logistics companies (e.g. DHL), airlines (e.g. Luxair Cargo), airports (e.g. Brussels Airport), electronic temperature recording instrument providers (e.g. Sensitech), etc. In this context, the relevant competent authorities in China have formulated and issued a series of rules and standards such as the national standard "Code for the Operation of Cold Chain Logistics of Drugs" (GB/T 28842) and the air transport industry standard "Code for Cold Chain Transportation of Cargo by Air" (MH/T 1058-2014) with reference to international rules and standards, combined with the actual national conditions of pharmaceutical vaccine production, storage and transportation.

In summary, with the rapid development of social economy, the state will strongly support and pay more attention to the construction of the pharmaceutical cold chain logistics system, and the relevant theoretical research will become increasingly perfect. Through the above research review, the literature help for the selection of vaccine air carriers of AD companies can be obtained, which is conducive to the analysis of the current situation and the construction of the evaluation index system. This paper takes AD's vaccine logistics as an example to use AHP to solve the practical problems of its air carrier selection, and at the same time serves as a reference for other enterprises involved in vaccine logistics.

3 Research methodology

This section will describe the methodology used in this paper, including a literature review of analytic hierarchy, specific implementation steps, data collection and data analysis methods.

3.1 Literature review of AHP

The analytic hierarchy method (AHP) was first proposed in the 70s of the 20th century by the famous operations researcher Professor Satie, who proposed the network system theory and comprehensive multi-objective comprehensive evaluation method of the University of Pittsburgh, and analyzed the hierarchical weight of decision-making. (Ma Ping 2018, 6-8.) In terms of AHP application in pharmaceutical logistics, Yan Lili and Fan Linbang (2021, 137-139) analyzed the investment value of cold chain logistics enterprises through AHP from the perspective of strategic analysis, focusing on the investment value of cold chain logistics enterprises, and providing new ideas for managers to maximize enterprise value. Cui Chenyue, Wang Renfang, Sun Dechao & Hong Xinhua (2021, 20-26) based on AHP-fuzzy comprehensive evaluation method to evaluate the logistics performance of fresh agricultural products enterprises, proposed that under today's market competition, it is particularly important for fresh agricultural products enterprises to have a good logistics performance evaluation, and made suggestions based on the calculation results.

3.2 Implementation steps

This study used analytic hierarchy to investigate AD's choice of vaccine air carriers. As a multi criteria decision-making method, AHP can fully consider the subjective will of decision-makers and the mutual influence of various factors, thus providing a scientific and reasonable decision-making basis for decision-makers. The implementation steps of AHP are as follows:

- Identify goals, guidelines, and scenarios: Identify the target, criterion, and scenario layers in the hierarchical model based on the purpose of the study.
- Build a hierarchy model: Build a hierarchy model based on goals, guidelines, and scenarios.
- Pairwise comparison: The criteria and scenario layers are evaluated using the pairwise comparison method.
- Calculate weight value: Use the feature root method to calculate the weight value of each criterion and scheme.
- Compare the combined priority of schemes: Compare the overall priority of each scenario based on the weight value and the pairwise comparison results.

3.3 Data collection

For analytic hierarchy calculations, this study needs to collect relevant data on air carriers. Appendix is a hierarchical analysis method scoring questionnaire, which is scored by ten respondents to provide data support for the calculation of this thesis. Please refer to Chapter 5 for the specific scoring results. The appendix is only the design table of the scoring questionnaire. Data sources include:

Public information: Collect data on the transportation costs, safety, timeliness and service quality of air carriers by consulting the airline's official website, industry reports, etc.

Expert Interviews: Invite AD insiders to conduct interviews about their evaluations and opinions on air carriers for pair-to-pair comparison. Please refer to Appendix 1 for the survey questionnaire and Appendix 2 for the interviewee information.

3.4 Data analysis

In this study, the data collected were analyzed using the analytic hierarchy method (AHP) as follows:

- The benchmark and scenario layers are evaluated using a pairwise comparison matrix.
- The feature root method is used to calculate the weight values of each criterion and scheme.
- Calculate the comprehensive priority of the scenario to determine the best air carrier.
- Through the above research methods, this study aims to provide AD companies with a scientific and reasonable method for selecting vaccine air carriers.

Through the above research methods, this study aims to provide AD Company with a scientific and reasonable method for selecting vaccine air carriers.

4 Current situation and problems of AD's vaccine cold chain logistics operation

This chapter will focus on the current situation and existing problems of AD Company's vaccine cold chain logistics operation. Cold chain logistics plays a crucial role in the transportation of vaccines, and its operational status directly affects the quality and safety of vaccines. By deeply understanding the actual operation of AD Company in vaccine cold chain logistics, this chapter will explore potential problems and challenges, and provide a basis for proposing improvement strategies in the future. This will help the thesis better understand the practical problems faced by AD company in vaccine cold chain logistics operation, and provide strong support for further optimizing cold chain logistics management.

4.1 Industry background of China's vaccine cold chain logistics operation

High demand for vaccines: China is one of the most populous countries in the world, and the demand for vaccines is very large. At the same time, with the continuous improvement of national medical insurance policies, more and more people can enjoy free or low-cost vaccination services. This has also promoted the development of the vaccine cold chain logistics industry.

High requirements for vaccine transportation: Vaccines are a high-value, high-risk cargo with very high requirements for transportation. Vaccines need to be transported under specific temperature and humidity conditions to ensure their quality and effectiveness. This places very high demands on the operation and management of vaccine cold chain logistics.

Healthcare system reform drives development: With the continuous reform and improvement of China's medical system, more and more hospitals and medical institutions have begun to use cold chain logistics to manage and transport vaccines. This also provides opportunities for the development of the vaccine cold chain logistics industry.

Strong policy support: The Chinese government has always attached great importance to the development of the vaccine cold chain logistics industry, and actively promoted the development of the vaccine cold chain logistics industry through policy support and financial support. For example, documents such as the "Vaccine Cold Chain Management Specification" issued by the National Health Commission have clarified and standardized the standardized management and requirements of vaccine cold chain logistics, providing a legal basis and policy support for the development of vaccine cold chain logistics.

Scientific and technological progress promotes development: With the continuous progress and application of logistics technology, the vaccine cold chain logistics industry has also been greatly

developed. For example, the application of temperature and humidity control technology, remote monitoring technology, Internet of Things technology, etc., can greatly improve the efficiency and quality of vaccine cold chain logistics and reduce operating costs.

In general, the industry background of China's vaccine cold chain logistics operation has huge market potential and development opportunities. Policy support, technological progress and growing market demand will provide strong support and guarantee for the development of the vaccine cold chain logistics industry.

4.2 AD Company Profile

AD Company is an international, high-tech bio-pharmaceutical enterprise that integrates the research and development, production, sales, distribution, and import and export of vaccines and biological products. Its main business is human vaccines, which are one of the seven strategic emerging industries in China. The currently sold product, namely the COVID-19 vaccine in this thesis, is the recombinant novel coronavirus protein vaccine (CHO cell) (Zhikeweide).

This section conducts multiple analysis of the current status of AD companies, including AD company vaccine supply, circulation methods, logistics operations, problems and countermeasure analysis, etc. At the same time, it also interviews ten company personnel.

4.2.1 AD supplies COVID vaccines

Company AD has a complete vaccine production line and strong technical research and development capabilities, and can provide customized vaccine products and services according to market demand and epidemic changes. Here is some information on AD's COVID vaccine supply:

- Vaccine Availability: AD's vaccine products cover the globe, including domestic and international markets. The company's vaccine products have entered many countries and regions around the world, and have been widely recognized and trusted by customers at home and abroad.
- Vaccine supply capability: AD has advanced vaccine production lines and a sound quality management system, which can realize large-scale production and supply of high-quality vaccine products. The company's vaccine supply capacity has been gradually increased to meet the growing market demand.
- Vaccine supply assurance: AD actively promotes vaccine cold chain logistics management and operation to ensure the temperature and humidity conditions of vaccines during transportation. At the same time, the company has also established a sound supply chain management system to ensure the reliability and stability of vaccine supply.

- Vaccine Supply Services: AD focuses on customer service and technical support and can provide customized vaccine products and services. The company's professional team can provide customers with a full range of technical support and consulting services to meet the different needs of customers.

Overall, AD has strong capabilities and advantages in vaccine supply to provide customers with high-quality, reliable and stable vaccine products and services. At the same time, the company also pays attention to vaccine cold chain logistics management and technological innovation, which provides strong guarantee and support for vaccine supply.

4.2.2 Distribution channels for AD's vaccines

- Medical institutions: AD's vaccine products are primarily sold and supplied through medical institutions. Medical institutions include hospitals, clinics, centers for disease control and prevention at all levels, etc., which are the main places for vaccine application and the main channels for vaccine sales and supply. By establishing stable partnerships with medical institutions at all levels, AD can supply vaccine products directly to customers.
- Distributors: AD also sells and supplies vaccines through a number of distributors and agents. These distributors and agents have their own sales networks and customer resources in various regions and markets, which can open up a broader market and customer base for AD's vaccine products.
- Online sales: With the popularity and development of the Internet, AD companies have also begun to sell vaccine products online. The company has opened vaccine sales channels on its own official website and some e-commerce platforms to facilitate customers to purchase vaccine products online.

AD's vaccine distribution channels are diverse, which can meet the needs and purchase methods of different customers. By establishing a stable cooperative relationship and sales network, the company can supply vaccine products to various regions and markets, and provide customers with diversified vaccine products and services.

4.2.3 AD Company's vaccine cold chain logistics operation method

Temperature and humidity control technology: AD uses advanced temperature and humidity control technology during vaccine transportation and storage to ensure that vaccines are transported and stored under specific temperature and humidity conditions. The company's transportation vehicles and warehouse equipment are equipped with professional temperature and humidity monitoring equipment, which can monitor and record the temperature and humidity of vaccines in time to ensure vaccine quality and safety.

Cold chain logistics management system: AD has established a complete cold chain logistics management system, which can monitor and manage the whole process of vaccine transportation and storage. The system can realize real-time monitoring and tracking of vaccine temperature, humidity, location and other information, and can also record and manage the quality and safety of vaccines.

Logistics Equipment and Packaging: AD uses specialized logistics equipment and packaging to transport and store vaccines. Transport vehicles and warehouse equipment are equipped with professional cold chain equipment and packaging materials to ensure the temperature and humidity conditions of the vaccine during transportation. At the same time, the company also uses special vaccine packaging materials and containers to ensure the quality and safety of vaccines during transportation and storage.

Professional training and management: AD attach great importance to personnel training and management of cold chain logistics operations. The company's logistics personnel have received professional training and assessment, and have mastered the relevant knowledge and skills of cold chain logistics. At the same time, the company has also established a professional cold chain logistics management team, which is responsible for supervising and managing cold chain logistics operations.

Third-party logistics: AD mainly includes transportation, warehousing, distribution, information management and other businesses in logistics outsourcing. The company entrusts part or all of its logistics business to a third-party logistics service provider for management and operation to improve logistics efficiency, reduce logistics costs and reduce risks. AD has established stable cooperation with a number of professional logistics service providers. These logistics service providers have rich experience and professional technology in logistics operations, and can provide companies with high-quality, reliable and stable logistics services. Through logistics outsourcing, logistics costs can be reduced, logistics efficiency can be improved, and risks can be reduced. At the same time, the company can use the professional technology and resources of third-party logistics service providers to improve the level of logistics operations and service quality, and reduce logistics management costs and risks.

AD takes a variety of approaches to vaccine cold chain logistics operations, ensuring the quality and safety of vaccines during transportation and storage through temperature and humidity control technology, cold chain logistics management systems, logistics equipment and packaging, professional training and management. The company continuously strengthens cold chain logistics management and technological innovation, improves the efficiency and quality of cold chain logistics operations, and provides customers with better service and guarantee. In addition, AD is

also actively exploring new technologies and methods in vaccine cold chain logistics operations, such as Internet of Things technology and remote monitoring technology, to improve the efficiency and quality of vaccine transportation and storage, and create more value.

4.3 Problems with AD's vaccine cold chain logistics operations

AD has made great progress and achievements in cold chain logistics, but there are still some problems and challenges. The company's personnel said that AD companies are lacking in long - distance transportation of vaccines.

> Interviewee 1: “Vaccine is sensitive to temperature, and cold chain logistics capabilities are critical to the quality and safety of the vaccine. AD currently has some shortcomings in cold chain logistics, and vaccine transportation cannot be performed long -distance, which may affect the quality of vaccine transportation.”
>
> Interviewee 2: “Due to the high requirements for time and temperature for vaccine transportation, the logistics cost is relatively high, increasing the company's operating costs.”
>
> Interviewee 3: “Emergency events may be faced during vaccine transportation, such as traffic accidents and natural disasters. AD companies' capabilities in responding to these emergencies need to be improved.”

Transportation distance restrictions: Vaccines are a high-risk cargo with very strict requirements for transportation conditions. At present, AD's cold chain logistics transportation distance is generally within 500 kilometers, and exceeding this range may have an impact on the quality and effectiveness of vaccines, limiting the circulation range and supply capacity of vaccines.

High transportation costs: The cost of cold chain logistics transportation is relatively high, mainly because of the need to use professional cold chain equipment and packaging materials, and the need to be equipped with professional logistics personnel and management systems. These costs affect vaccine pricing and market competitiveness.

Low vaccine distribution efficiency: At present, the vaccine circulation efficiency of AD needs to be improved. Due to the large demand for cold chain logistics, logistics operations are difficult, which may lead to inefficient circulation of vaccines and affect the supply and quality of vaccines.

Insufficient application of technology: Although AD has adopted some advanced technologies and methods to improve the efficiency and quality of cold chain logistics operations, there is still a certain gap compared with the international advanced level. The company needs to further

strengthen technological innovation and application, and improve the level and competitiveness of cold chain logistics operations.

Logistics outsourcing is risky: Since logistics services are an important link between the company and customers, if the service quality of the third-party logistics service provider is poor, it may have a negative impact on the company's image, which may affect the quality of logistics operations and customer satisfaction. Logistics outsourcing involves important information transmission and management, and if the information security measures of third-party logistics service providers are not in place, it may lead to information leakage and security problems. In addition, logistics outsourcing requires the establishment of stable cooperative relations with third-party logistics service providers, and if the partners have business difficulties or changes in business policies, it may affect the stability and reliability of logistics operations.

4.4 Cause analysis

AD Cold Chain Logistics SWOT Analysis:

4.4.1 Strength

Professional vaccine production and sales experience, with perfect vaccine production line and quality management system, can ensure the quality and safety of vaccines;

It has established a sound vaccine cold chain logistics management and operation system, using advanced temperature and humidity control technology and cold chain logistics management system, etc., which can ensure the quality and safety of vaccines during transportation and storage;

The company has established a stable vaccine supply channel and sales network, which can meet the needs and purchasing methods of different customers.

4.4.2 Weakness

The high cost of cold chain logistics and transportation may affect the pricing and market competitiveness of vaccines;

Limited transport distances may limit the range and supply capacity of vaccines.

4.4.3 Opportunity

The growing demand for vaccines at home and abroad provides more opportunities and market space;

Government support for vaccine production and distribution, providing policy and financial support;

The emergence of new technologies and methods, such as Internet of Things technology and remote monitoring technology, can improve the efficiency and quality of cold chain logistics operations and create more value.

4.4.4 Threat

Fierce competition and challenging market share;

There are certain policy and legal risks in the vaccine market, which may affect vaccine production and sales;

Increasing competition and regulatory requirements in international markets may place higher demands and challenges on vaccine cold chain logistics operations.

In summary, AD cold chain transportation has certain advantages in management and technology, but there are also disadvantages such as high cost and limited transportation distance. At the same time, the growing demand for vaccines at home and abroad and the emergence of new technologies also provide opportunities and development space for companies, while market competition and regulatory requirements also pose threats and challenges. According to the results of SWOT analysis, the company needs to further strengthen the management and technological innovation of cold chain logistics, improve transportation efficiency and quality, reduce operating costs, and provide customers with better service and guarantee.

4.5 Scheme

Company AD currently cooperates with the following three airlines, and this thesis aims to provide reference for selecting the optimal solution through AHP.

Air China Cargo (2020) : By June 2019, Air China Cargo had a total of 19 freight routes, including 13 international routes, 1 regional route, 5 domestic routes; navigation countries (regions) There are 8 navigation cities (including 11 internationally, 1 region, and 9 in China). At the same time, relying on Air China ’s global route network, domestic cargo Airlines has 773 air transport routes worldwide, of which 139 international routes, 29 regional routes, 605 domestic routes, 41 global navigable countries (regions), and 197 navigation cities 197 (Among them, there are 74 internationally, 3 regions, and 120 domestic). As an aviation transportation company with more than 50 years of freight development, Sinotrans has participated in the launch and formulation of a number of air cargo transportation standards in China. Reliable transportation solutions.

China Eastern Cargo (2022) : Relying on more than 700 passenger aircraft compartment of China Eastern Airlines and more than ten shipping machines in China Shipping, with the help of the

Tianhe Alliance Network, China Eastern Airlines Logistics has built a nationwide and radiating global route network. , Formed a unique resource advantage. Relying on the "Heaven and Earth Unite" resource guarantee and diversified pan-Air logistics product service system, China Eastern Cargo sets aviation speed, cargo stations, multi-type transportation, special storage, cross-border e-commerce, supply chain services, aviation special goods, special goods of aviation special goods The solution and the direct business functions such as direct origin are integrated. In operational practice, it has cultivated and formed full logistics services and resource integration capabilities such as design, optimization, organization, implementation, and management.

China Southern Cargo (2019) : The establishment of China Southern Cargo Logistics is not only a specific action to implement the new requirements of state -owned enterprise reform, but also to integrate freight resources, establish a market -oriented business mechanism, form a complete aviation logistics industry chain, and create a key carrier of comprehensive logistics service providers with aviation characteristics. Relying on the developed domestic and international routes of China Southern Cargo, it can provide densely covering domestic, comprehensively radiating Asia, and connecting abdominal capacity services in major cities in Europe, the United States, Australia, and Africa. At present, China Southern Cargo operates more than 860 passenger and cargo aircraft, and the fleet is ranked first in Asia in size and third in the world.

These three vaccine air carriers have strong advantages in market share, service network, professional capabilities, reputation and reputation, etc., and are suitable as the choice of Chinese vaccine air carriers.

5 Calculations and Results

Through the above literature and current situation research, this chapter will select suitable indicators and build an evaluation index system, and based on this, each index and air carrier will be scored and evaluated, and finally detailed data and results will be listed.

5.1 Indicator selection

This paper refers to the principles and ideas of relevant domestic and foreign scholars in selecting evaluation indicators, collects the opinions of ten senior executives of AD Company and related industry experts through interviews, and follows the principles of comprehensiveness, scientificity, rationality, purpose and operability when selecting evaluation indicators based on the development of cold chain logistics. From a comparative analysis from multiple aspects, it is believed that the following indicators should be selected by vaccine cold chain logistics air carriers:

a) Temperature control capability (Wang Yaoyao, Xu Wen, Huang Yan, Wang Jingren, Li Qian, Xu Fa, Zhao Xiaohong & Tang Jintian. 2018, 90-93): Vaccines are high-risk goods with very strict temperature requirements. Air carriers should have advanced temperature control technologies and equipment to ensure temperature stability and control of vaccines during transportation.
b) Transportation timeliness (Wu Xuanyu. 2021): Air transportation is an important part of vaccine cold chain logistics, and it should have efficient and fast transportation timeliness to ensure that vaccines arrive at their destination in time and maintain quality and effectiveness.
c) Quality of service (Zhou Yanglin. 2018): Air carriers should have good quality of service, including customer service, flight accuracy, cargo tracking, etc., to ensure smooth and efficient vaccine transportation.
d) Cost-effectiveness (Zhao Jiaoyun & Lin Zhenqiang. 2021, 50-53): The cost of air transportation of vaccine cold chain logistics is high, and air carriers should have efficient transportation networks and cost control capabilities to ensure the economy and sustainability of vaccine cold chain logistics transportation.

In summary, the selection of air carrier indicators of vaccine cold chain logistics is considered from the aspects of temperature control ability, safety management ability, transportation timeliness, service quality and cost-effectiveness to ensure the quality, safety and efficiency of vaccines in the air transportation process.

5.2 System construction

5.2.1 Benchmark-level specific indicators

In this paper, the AHP analytic hierarchy method is used to construct an evaluation index system composed of target layer, primary index and secondary index, and the comprehensive evaluation of the vaccine cold chain logistics air carrier of Five AD Company is carried out. Based on the reference to the vaccine cold chain logistics index system and the actual situation of air carriers in the region, this paper establishes the following evaluation index system.

The specific indicators are shown in Figure 3:

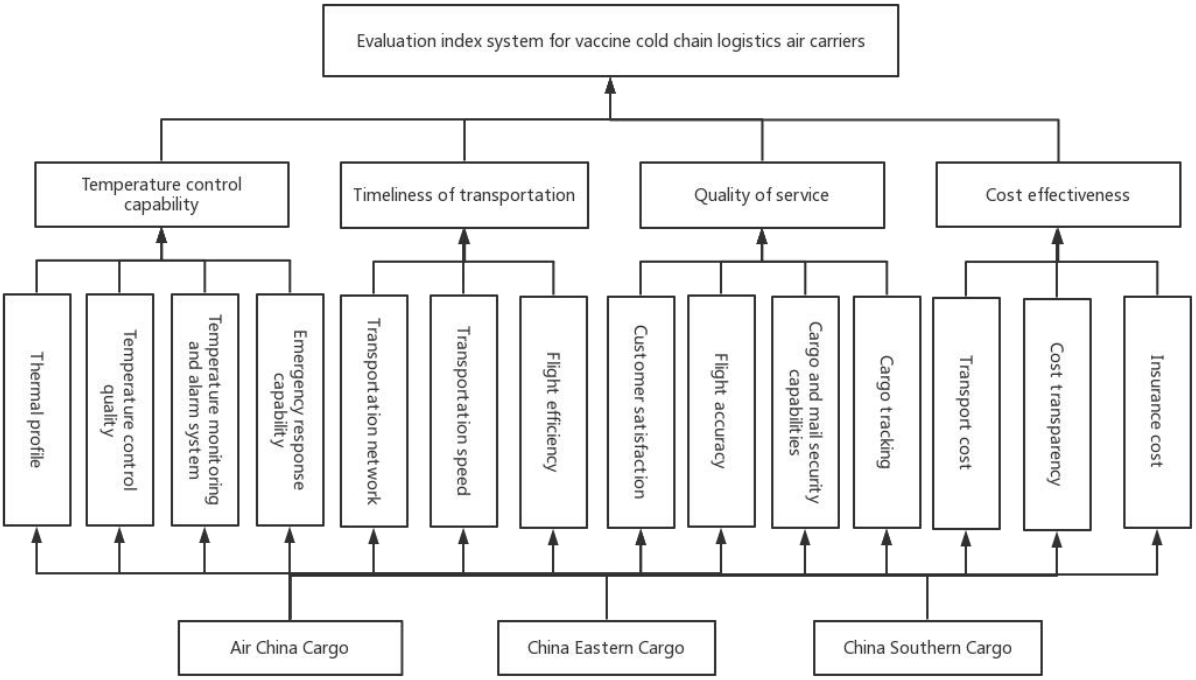

Figure 3. Evaluation index system of air carriers in vaccine cold chain logistics

5.2.2 Hierarchical structure

This paper constructs the evaluation index system of vaccine cold chain logistics air carriers, and divides the index system into target layer (vaccine cold chain logistics air carrier evaluation) and first-level evaluation index (based on the systematic principle of taking into account the elements contained in vaccine cold chain logistics carriers). 4 items such as temperature control ability, transportation timeliness, service quality, cost-effectiveness, etc.), and secondary evaluation indicators (14 items such as temperature control technology and temperature control quality). The target layer of this evaluation is: Evaluation of air carriers in vaccine cold chain logistics.

The specific indicators are shown in Table 2:

Total indicators	Level 1 evaluation indicators	Secondary evaluation indicators
Vaccine cold chain logistics air carrier evaluation A	Temperature control capability B_1	Temperature control technology C_{11}, temperature control quality C_{12}, temperature monitoring and alarm system C_{13}, emergency handling capacity C_{14}
	Timeliness B_2	Transport network C_{21}, transport speed C_{22}, flight frequency C_{23}
	Quality of Service B_3	Customer satisfaction C_{31}, flight accuracy $C3_2$, cargo and mail security capability C_{33}, cargo tracking C_{34}
	Cost-effective B_4	Transportation costs C_{41}, cost transparency C_{42}, insurance costs C_{43}

Table 2. Evaluation index system of vaccine cold chain logistics air carriers

5.2.3 Construct an analytic hierarchy matrix

This paper adopts the analytic hierarchy method, consults 10 experts in related industries to score according to the development status of air logistics in Chongqing, and determines the weight of each index. According to Table 3 Construct a judgment matrix.

Table 3. Analytic hierarchy 1-9 measurement table

Importance level	illustrate
1	The two have the same importance when compared
3	Compared with the two, the former is slightly more important than the latter
5	Compared with the two, the former is obviously more important than the latter
7	Compared with the two, the former is more important than the latter
9	Compared with the two, the former is extremely important than the latter
reciprocal	If the judgment of the comparison between i and j is a ij, then the judgment of the comparison between j and i is $a_{ji}=1/a_{ij}$

The scoring situation is now statistically analyzed, and the statistical evaluation results are as follows.

5.2.3.1 First-level indicator judgment matrix

First, the four first-level indicators are compared in pairs relative to the overall target, and the following judgment matrix is obtained, see Table 4.

Table 4. Judgment matrices A-B

A	Temperature control capability B_1	Timeliness B_2	Quality of Service B_3	Cost-effective B_4
Temperature control capability B_1	1	1/2	1/3	3
Timeliness B_2	2	1	1/2	3
Quality of Service B_3	3	2	1	3
Cost-effective B_4	1/3	1/3	1/3	1

5.2.3.2 Secondary indicator judgment matrix

(1) Will Temperature control technology, temperature control quality, temperature monitoring and alarm system, emergency handling capacity are compared, and the judgment matrix is shown in Table 5.

Table 5. Judgment matrix B_1-C_1

B_1	Temperature control technology C_{11}	Temperature controlled mass C_{12}	Temperature monitoring and alarm system C_{13}	Emergency Response Capacity C_{14}
Temperature control technology C_{11}	1	1/3	1/2	1/3
Temperature controlled mass C_{12}	3	1	3	1/2
Temperature monitoring and alarm system C_{13}	2	1/3	1	1/3
Emergency Response Capacity C_{14}	3	2	3	1

(2) Will The transportation network, transportation speed and flight frequency are compared in pairs, and the judgment matrix is obtained in Table 6.

Table 6. Judgment matrix B_2-C_2

B_2	Transport network C_{21}	Transport speed C_{22}	Flight frequency C_{23}
Transport network C_{21}	1	1/3	1/2
Transport speed C_{22}	3	1	3
Flight frequency C_{23}	2	1/3	1

(3) Will Customer satisfaction, flight accuracy, cargo and mail security capabilities, and cargo tracking were compared in pairs, and the judgment matrix was obtained in Table 7.

Table 7. Judgment matrix B_3-C_3

B_3	Customer satisfaction C_{31}	Flight accuracy C_{32}	Cargo and mail security capability C_{33}	Cargo Tracking C_{34}
Customer satisfaction C_{31}	1	4	4	4
Flight accuracy C_{32}	1/4	1	3	3
Cargo and mail security capability C_{33}	1/4	1/3	1	1/2
Cargo Tracking C_{34}	1/4	1/3	2	1

(4) Will Transportation costs, cost transparency, and insurance costs are compared in pairs, and the judgment matrix is obtained in Table 8.

B_4	Shipping cost C_{41}	Fee transparency C_{42}	Insurance cost C_{43}
Shipping cost C_{41}	1	2	1/3
Fee transparency C_{42}	1/2	1	1/4
Insurance cost C_{43}	3	4	1

Table 8. Judgment matrix B_4-C_4

5.2.3.3 Scenario layer judgment matrix

Ibid., comparing the indicators in pairs at the programme level yields a judgement matrix as shown in Table 9.

Table 9. Scheme layer judgment matrix

C_{11}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{12}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	3	2	Air China Cargo	1	3	2
Eastern Airlines Cargo	1/3	1	1/2	Eastern Airlines Cargo	1/3	1	1/3
Southern	1/2	2	1	Southern	1/2	3	1

Air Cargo				Air Cargo			
C_{13}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{14}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	2	3	Air China Cargo	1	4	3
Eastern Airlines Cargo	1/2	1	3	Eastern Airlines Cargo	1/4	1	1/2
Southern Air Cargo	1/3	1/3	1	Southern Air Cargo	1/3	2	1
C_{21}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{22}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	1/2	1/3	Air China Cargo	1	1/2	1/4
Eastern Airlines Cargo	2	1	1/2	Eastern Airlines Cargo	2	1	1/2
Southern Air Cargo	3	2	1	Southern Air Cargo	4	2	1
C_{23}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{31}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	1/2	1/4	Air China Cargo	1	1/2	1/4
Eastern Airlines Cargo	2	1	1/3	Eastern Airlines Cargo	2	1	1/3
Southern Air Cargo	4	3	1	Southern Air Cargo	4	2	1
C_{32}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{33}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	3	3	Air China Cargo	1	3	1/3
Eastern Airlines Cargo	1/3	1	1/2	Eastern Airlines Cargo	1/3	1	1/4

Southern Air Cargo	1/3	2	1	Southern Air Cargo	3	4	1
C_{34}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{41}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	4	3	Air China Cargo	1	1/2	1/3
Eastern Airlines Cargo	1/4	1	1/2	Eastern Airlines Cargo	2	1	1/2
Southern Air Cargo	1/3	2	1	Southern Air Cargo	3	2	1
C_{42}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	C_{43}	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo
Air China Cargo	1	2	2	Air China Cargo	1	1/2	1/3
Eastern Airlines Cargo	1/2	1	1/2	Eastern Airlines Cargo	2	1	1/3
Southern Air Cargo	1/2	2	1	Southern Air Cargo	3	3	1

5.2.4 Hierarchy sorting and consistency checking

According to the relationship between the overall goal and each index in the hierarchical model diagram, the judgment matrices A-B, B_1-C_1, B_2-C_2, B_3-C_3, B_4-C_4 and the scheme level judgment matrix are constructed. On this basis, the geometric mean method is used to calculate the corresponding eigenvectors and eigenvalues, and the eigenvectors are normalized to obtain the corresponding weight vector matrix $W=(W_1, W_2,..., W_n)^T$. At the same time, the consistency of all eigenvectors is checked. This thesis conducts specific operations on the A-B hierarchical judgment matrix, which is divided into the following steps:

First, find the product of the elements of each row and open the product to the nth power, as shown in Table 10 is shown.

Table 10. The product of the rows of the primary indicator and the root to the nth power

	Row product	nth power root

Temperature control capability	0.50	0.84
Timeliness of transportation	4.50	1.46
Quality of service	18.00	2.06
Cost-effective	0.04	0.44

Second, find the determination matrix feature vector.

$$w_i = \frac{w_i^{'}}{\sum_{j=1}^{n} w_i^{'}} = \begin{matrix} 0.1855 \\ 0.2769 \\ 0.4392 \\ 0.0984 \end{matrix}$$

Third, calculate the maximum feature root of the judgment matrix.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(BW)_i}{nw_i} = \frac{\sum_{i=1}^{n} \frac{(BW)_i}{w_i}}{n} = 4.1451$$

Fourth, consistency check.

$$CI = \frac{\lambda_{max} - n}{n-1} = 0.0484$$

According to the RI values of consistency test in Table 11, it can be seen that when the order is 4, the RI value of the matrix is 0.89, indicating the random consistency ratio of the fourth order matrix:

$$CR = \frac{CI}{RI} = \frac{0.0201}{0.89} = 0.0543 < 0.1$$

The RI value of the consistency test is the query value used in the process of consistency test of the hierarchical analysis method, which is the average value obtained after 500 sampling tests by scientists. It is generally applied to the consistency test of judgment matrix.

Table 11. Consistency check for RI values

Order	1	2	3	4	5	6	7	8	9	…
RI value	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	…

It can be seen from CR<0.1 that the matrix has satisfactory consistency, and the weight of the first-level indicators for the overall goal is:

(W_1, W_2, W_3, W_4) = (0.1855, 0.2769, 0.4392, 0.0984)

The same calculation process as above, by judging matrices A-B, B_1-C_1, B_2-C_2, B_3-C_3 , B_4-C_4 and the calculation of the scheme layer judgment matrix, resulting in Table 12, 13.

Table 12. Single-level sorting table of primary and secondary indicators

First-level metric weights	Secondary metric weights		Consistency check
Temperature control capability B_1 0.1855	Temperature control technology C_{11}	0.1056	λmax=4. 1222 CR=0. 0458<0.1
	Temperature controlled mass C_{12}	0.3092	
	Temperature monitoring and alarm system C_{13}	0.1501	
	Emergency Response Capacity C_{14}	0.4351	
Timeliness B_2 0.2769	Transport network C_{21}	0.5889	λmax=3.0539 CR=0. 0518<0.1
	Transport speed C_{22}	0.1593	
	Flight frequency C_{23}	0.2519	
Quality of Service B_3 0.4392	Customer satisfaction C_{31}	0.537	λmax=4. 2178 CR=0.0816<0. 1
	Flight accuracy C_{32}	0.0901	
	Cargo and mail security capability C_{33}	0.2431	
	Cargo Tracking C_{34}	0.1298	
Cost-effective B_4 0.0984	Shipping cost C_{41}	0.6232	λmax=3.0183 CR=0.0176<0. 1
	Fee transparency C_{42}	0.1373	
	Insurance cost C_{43}	0.2395	

Table 13. Scheme layer single-level sort table

Index	Air China Cargo	Eastern Airlines Cargo	Southern Air Cargo	Consistency check
Temperature control technology C_{11}	0.539	0.1638	0.2973	λmax=3.0092 CR=0.0089<0.1
Temperature controlled mass C_{12}	0.5247	0.1416	0.3338	λmax=3.0538

				CR=0.0517<0.1
Temperature monitoring and alarm system C_{13}	0.5247	0.3338	0.1416	λmax=3.0538
				CR=0.0517<0.1
Emergency Response Capacity C_{24}	0.5714	0.1429	0.2857	λmax=3.0000
				CR=0.0000<0.1
Transport network C_{21}	0.1429	0.2857	0.5714	λmax=3.0000
				CR=0.0000<0.1
Transport speed C_{22}	0.1638	0.2973	0.539	λmax=3.0092
				CR=0.0089<0.1
Flight frequency C_{23}	0.1373	0.2395	0.6232	λmax=3.0183
				CR=0.0176<0.1
Customer satisfaction C_{31}	0.1373	0.2395	0.6232	λmax=3.0183
				CR=0.0176<0.1
Flight accuracy C_{32}	0.2721	0.1199	0.608	λmax=3.0741
				CR=0.0713<0.1
Cargo and mail security capability C_{33}	0.5889	0.1593	0.2519	λmax=3.0539
				CR=0.0518<0.1
Cargo Tracking C_{34}	0.6232	0.1373	0.2395	λmax=3.0183
				CR=0.0176<0.1
Shipping cost C_{41}	0.1593	0.2519	0.5889	λmax=3.0539
				CR=0.0518<0.1
Fee transparency C_{42}	0.4905	0.1976	0.3119	λmax=3.0537
				CR=0.0517<0.1
Insurance cost C_{43}	0.1638	0.2973	0.539	λmax=3.0092
				CR=0.0089<0.1

5.2.5 Hierarchical total sorting

On the basis of hierarchical single ranking, the weight value of each indicator for the total target is obtained, and the overall ranking of the hierarchy is carried out, and the results are shown in Table 14-16.

Table 14. Ranking of first-level evaluation index weight results of vaccine cold chain logistics air carriers

Level 1 indicators	Weight	Ranking
Quality of service	0.4392	1
Timeliness of transportation	0.2769	2
Temperature control capability	0.1855	3
Cost-effective	0.0984	4

Table 15. Ranking of weight results of secondary evaluation indicators of vaccine cold chain logistics air carriers

Level 2 indicators	Weight	Ranking
Customer satisfaction	0.2359	1
Transportation network	0.163	2
Cargo and mail security capabilities	0.1068	3
Emergency response capabilities	0.0807	4
Flight efficiency	0.0697	5
Shipping costs	0.0613	6
Temperature-controlled quality	0.0574	7
Shipment tracking	0.057	8
Speed of transportation	0.0441	9
Flight accuracy	0.0396	10
Temperature monitoring and alarm system	0.0278	11
Insurance costs	0.0236	12
Temperature control technology	0.0196	13
Fee transparency	0.0135	14

Table 16. Ranking of scheme layer weight results

Alternatives	Weight	Ranking
Southern Air Cargo	0.477	1
Air China Cargo	0.3033	2
Eastern Airlines Cargo	0.2197	3

The content of the above form is the calculation results and weight sorting of this chapter, providing data support and reference value for the evaluation analysis and conclusions of the post.

6 Discussion

This chapter is based on the calculation results of the AD company to choose the optimal solution for the AD company vaccine and aviation carrier, and refer to the opinions of expert interviews with AD companies and other related industry companies to propose vaccine transportation suggestions and aviation carrier selection suggestions. It has certain reference value.

6.1 Evaluation analysis

This chapter is based on the calculation results of the AD company to choose the optimal solution for the AD company vaccine and aviation carrier, and refer to the opinions of expert interviews with AD companies and other related industry companies to propose vaccine transportation suggestions and aviation carrier selection suggestions. It has certain reference value.

Based on the above calculation results and sorting, the following analysis can be obtained:

Service Quality: When choosing a vaccine cold chain logistics and aviation carrier, service quality should be considered the primary consideration. This includes customer satisfaction, flight accuracy, cargo safety capacity and cargo tracking. Zhou Yanglin mentioned that the medical cold chain logistics service is the delivery of refrigerated drugs, according to the required time and place, the quality and quantity of the quality and quantity to the customer, to meet the needs of customers and the value of the value of enterprises and customers. Quality occupies an important position in vaccine aviation transportation, and should be used as the primary consideration for selecting aviation carrier. In this indicator, the overall performance of China Southern Cargo is relatively good.

Transportation timeliness: Transportation timeliness is a key factor in vaccine cold chain logistics, including transportation networks, transportation speed and flight frequency. Du Xinyi proposed that the occurrence of the COVID-19 vaccine has spawned the demand for huge vaccine cold chain logistics, but it also brings many problems. To solve these problems, we must optimize the structure, equipment, technology, and personnel of the entire vaccine cold chain supply chain. Block-chain technology and social logistics companies will bring new development driving for traditional vaccine cold chains. In this indicator, China Southern Cargo has a greater advantage.

Temperature control capacity: Temperature control capabilities are essential for vaccine quality and effectiveness. Temperature control technology, temperature control quality, temperature monitoring and alarm system, and emergency response capabilities are the key factor in evaluating the ability of temperature control. This is always required to echo and transport the entire process of vaccine from production to vaccination. The most basic principle of vaccine cold chain logistics

is to ensure that the chain cannot be "disconnected", otherwise it may cause the vaccine's active ingredients to lose and affect the health and safety of the vaccinator. According to the relevant provisions of the new version of the "Management of Drug Management", the cold chain transportation process of the vaccine should strictly control the temperature range. In this indicator, Air China Cargo dominates, with a complete and strict temperature control system.

Cost benefits: Cost and benefits are important indicators to measure the comprehensive strength of vaccine cold chain logistics and aviation carrier, including transportation costs, transparency costs, and insurance costs. This also confirms that Li Fei proposes the cost of controlling aviation carrier. In this indicator, China Southern Cargo is dominant.

Based on the above evaluation suggestions, Company AD can give priority to Air China Cargo when selecting vaccine cold chain logistics air carriers, followed by China Eastern Cargo and China Southern Cargo. At the same time, each party should comprehensively consider the weight of each evaluation index and the specific performance of air carriers according to their own needs and actual conditions, so as to ensure the smooth progress of the vaccine cold chain logistics process and the guarantee of vaccine quality.

Interviewees of AD companies propose some vaccine logistics, and they said that AD company need to strengthen cooperation with third-party logistics companies.

> Interviewee 4: “The standardization and rigorous requirements of medical cold chain logistics operations are high, and the investment in hardware and software, personnel quality and training requirements are also very high. Therefore, it is necessary to introduce the concept of lean management, thereby improving the overall level of operation of the cold chain logistics of the medicine, and achieving the purpose of cost control and ensuring profitability.”
>
> Interviewees 5: “AD companies should pay attention to the construction and maintenance of cold chain logistics facilities to ensure that the temperature control of the vaccine during transportation meets the requirements. In addition, you can consider cooperating with professional cold chain logistics companies to improve the quality of vaccine transportation with its professional capabilities.”
>
> Interviewees 6: “AD companies can reduce logistics costs by optimizing logistics lines, improving transportation efficiency, and adopting advanced transportation tools. At the same time, strengthen cooperation with logistics companies and strive to get more reasonable transportation prices.”

> Interviewees 7: “AD companies should establish an early warning mechanism and emergency plan to deal with emergencies to improve their ability to deal with emergencies. For example, strengthen the communication and coordination of the aviation carrier, as well as governments and rescue departments from various governments, and rescue departments to ensure that emergency response can be started quickly when emergencies occur and reduce losses.”

6.2 Suggestion

When actually choosing an air carrier, various companies should pay attention to the following:

Air carrier expertise and experience: Learn about air carriers' expertise and experience in vaccine cold chain logistics to assess whether they can meet vaccine transportation requirements in practice.

Air carrier equipment and facilities: Examine air carrier equipment and facilities, such as refrigerated vehicles, warehouses and means of transport, to ensure they meet stringent standards for vaccine cold chain transportation.

Air carriers' emergency response mechanisms: Understand the emergency response capabilities of air carriers in the face of emergencies, such as temperature abnormalities, flight delays, etc., and assess whether they can take timely measures to ensure vaccine quality in an emergency.

Air carrier partners: Evaluate air carriers' partners in vaccine cold chain logistics, such as ground transporters, warehousing service providers, etc., to ensure smooth operation throughout the supply chain.

Air carrier reputation and reputation: Learn about the reputation and reputation of air carriers in the industry and get information about their service level and quality from other customers' reviews.

In short, when choosing an air carrier for vaccine cold chain logistics, you should weigh various factors according to the actual performance of each evaluation index and your own needs to ensure that you choose the best partner.

7 Conclusion

In this paper, a set of evaluation index systems is proposed for the selection of air carriers of AD's vaccine cold chain logistics, including temperature control ability, service quality, transportation timeliness and cost-effectiveness. According to the evaluation index system, it provides a reference for the selection of air carriers for vaccine cold chain logistics.

Through the analysis of the evaluation indicators of three air carriers, Air China Cargo, China Eastern Cargo and China Southern Cargo, in four aspects: service quality, transportation timeliness, temperature control ability and cost-effectiveness, the comprehensive evaluation results show that China Southern Air Cargo performs relatively well in four aspects and is the preferred partner. China Eastern Cargo and China International Cargo also perform relatively well in all indicators and can be used as alternative partners. In the actual selection process, the weight of each evaluation index and the specific performance of air carriers should be comprehensively considered to ensure the smooth progress of the vaccine cold chain logistics process and the guarantee of vaccine quality.

At the same time, government regulators, vaccine manufacturers and logistics companies should pay attention to factors such as their professional competence and experience, equipment and facilities, emergency response mechanisms, partners, and credibility and reputation when selecting air carriers, so as to more fully assess their comprehensive strength.

In conclusion, the choice of air carriers for vaccine cold chain logistics is particularly important during the critical period of vaccination on a global scale. Through the comprehensive evaluation and analysis of air carriers, it helps to ensure the smooth operation of the vaccine cold chain logistics process and provides strong support for global vaccination.

There are still many shortcomings in the thesis. Due to the limitation of time and energy and personal ability, the research is mainly based on AD companies. Although the vaccine company and aviation carrier should strictly abide by relevant laws and regulations in vaccine transportation, they should strictly abide by relevant laws and regulations. However, There are still deviations. The conclusion of this thesis hopes to contribute to the subsequent research on vaccine logistics.

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Appendices

Appendix 1

1. Scoring rules

Analytic hierarchy 1-9 measurement table

Importance level	Illustrate
1	The two have the same importance when compared
3	Compared with the two, the former is slightly more important than the latter
5	Compared with the two, the former is obviously more important than the latter
7	Compared with the two, the former is more important than the latter
9	Compared with the two, the former is extremely important than the latter
reciprocal	If the judgment of the comparison between i and j is a ij, then the judgment of the comparison between j and i is $a_{ji}=1/a_{ij}$

2. Evaluation scoring table

Please fill in the rating results in the following table:

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. Which indicator is more important for vaccine air logistics and air carriers?				
Temperature control capability B_1		1 2 3 4 5 6 7 8 9		Timeliness of transportation B_2
Temperature control capability B_1		1 2 3 4 5 6 7 8 9		Quality of service B_3
Temperature control capability B_1		1 2 3 4 5 6 7 8 9		Cost-effective B_4
Timeliness of transportation B_2		1 2 3 4 5 6 7 8 9		Quality of service B_3

Timeliness of transportation B_2		1 2 3 4 5 6 7 8 9		Cost-effective B_4
Quality of service B_3		1 2 3 4 5 6 7 8 9		Cost-effective B_4

a. Layer 1 elements

b. Layer 2 elements

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of "Temperature control capability B_1" ?				
Temperature control technology C_{11}		1 2 3 4 5 6 7 8 9		Temperature controlled mass C_{12}
Temperature control technology C_{11}		1 2 3 4 5 6 7 8 9		Temperature monitoring and alarm system C_{13}
Temperature control technology C_{11}		1 2 3 4 5 6 7 8 9		Emergency Response Capacity C_{14}
Temperature controlled mass C_{12}		1 2 3 4 5 6 7 8 9		Temperature monitoring and alarm system C_{13}
Temperature controlled mass C_{12}		1 2 3 4 5 6 7 8 9		Emergency Response Capacity C_{14}
Temperature monitoring and alarm system C_{13}		1 2 3 4 5 6 7 8 9		Emergency Response Capacity C_{14}

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of "Timeliness of transportation B_2" ?				
Transport network C_{21}		1 2 3 4 5 6 7 8 9		Transport speed C_{22}
Transport network C_{21}		1 2 3 4 5 6 7 8 9		Flight frequency C_{23}
Transport speed C_{22}		1 2 3 4 5 6 7 8 9		Flight frequency C_{23}

Index	Importance comparison	Index
Compare the elements in pairs between the following groups. What is the relative importance of		

“Quality of Service B_3” ?				
Customer satisfaction C_{31}		1 2 3 4 5 6 7 8 9		Flight accuracy C_{32}
Customer satisfaction C_{31}		1 2 3 4 5 6 7 8 9		Cargo and mail security capability C_{33}
Customer satisfaction C_{31}		1 2 3 4 5 6 7 8 9		Cargo Tracking C_{34}
Flight accuracy C_{32}		1 2 3 4 5 6 7 8 9		Cargo and mail security capability C_{33}
Flight accuracy C_{32}		1 2 3 4 5 6 7 8 9		Cargo Tracking C_{34}
Cargo and mail security capability C_{33}		1 2 3 4 5 6 7 8 9		Cargo Tracking C_{34}

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Cost-effective B_4” ?				
Shipping cost C_{41}		1 2 3 4 5 6 7 8 9		Fee transparency C_{42}
Shipping cost C_{41}		1 2 3 4 5 6 7 8 9		Insurance cost C_{43}
Fee transparency C_{42}		1 2 3 4 5 6 7 8 9		Insurance cost C_{43}

c. Layer 3 elements

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Temperature control technology C_{11}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison	Index

Compare the elements in pairs between the following groups. What is the relative importance of "Temperature controlled mass C_{12} ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of "Temperature monitoring and alarm system C_{13}" ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of "Emergency Response Capacity C_{14}" ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of "Transport network C_{21}" ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo

Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Transport speed C_{22}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Flight frequency C_{23}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Customer satisfaction C_{31}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index		Importance comparison		Index
Compare the elements in pairs between the following groups. What is the relative importance of “Flight accuracy C_{32}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index		Importance comparison		Index
Compare the elements in pairs between the following groups. What is the relative importance of “Cargo and mail security capability C_{33}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index		Importance comparison		Index
Compare the elements in pairs between the following groups. What is the relative importance of “Cargo Tracking C_{34}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison	Index
Compare the elements in pairs between the following groups. What is the relative importance of “Shipping cost C_{41}” ?		

Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Fee transparency C_{42}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

Index	Importance comparison			Index
Compare the elements in pairs between the following groups. What is the relative importance of “Insurance cost C_{43}” ?				
Air China Cargo		1 2 3 4 5 6 7 8 9		China Eastern Cargo
Air China Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo
China Eastern Cargo		1 2 3 4 5 6 7 8 9		China Southern Cargo

The questionnaire is over. Thank you for your cooperation！

Disclaimer: This table is design table. Please refer to Chapter 5 for the specific scoring value.

Appendix 2

The following table records the interviewees from AD Company and their approximate interview content.The interviews were conducted through structured interviews in which ten personnel were asked for their suggestions, and depending on the position they were asked to discuss their responses around the topics of air carriers and vaccine transportation.

Interviewees	Position	Interview content	Time
1	AD Company R&D Department Manager	Scoring; understand the temperature and equipment conditions for vaccine transportation, and inquire about cold chain transportation issues and suggestions.	2023-1-19
2	Logistics Manager of AD Company	Scoring; understand the problems and solutions in the company's logistics.	2023-1-19
3	Logistics Manager of AD Company	Scoring; understand the temperature and equipment conditions for vaccine transportation, and inquire about cold chain transportation issues and suggestions.	2023-1-19
4	AD Company R&D Department Manager	Scoring; Understand the problems and solutions in the company's logistics.	2023-1-19
5	AD Company Business Manager	Scoring; ask the company's partners about the problems and solutions of third-party logistics.	2023-1-19
6	AD Company Business Manager	Scoring; ask the company's partners about the problems and solutions of third-party logistics.	2023-1-19
7	AD company vaccine transportation personnel	Scoring; ask about the problems and emergency plans in transportation.	2023-2-13
8	AD company vaccine transportation personnel	Scoring; ask about the problems and emergency plans in transportation.	2023-2-13
9	AD Company Cold Storage Manager	Scoring; understand the storage conditions of vaccines and potential issues that may arise when entering or exiting the warehouse.	2023-2-13
10	AD Company Cold Storage Manager	Scoring; understand the storage conditions of vaccines and potential issues that may arise when entering or exiting the warehouse.	2023-2-13