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Research on optimization of a company's agricultural products cold chain logistics system

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Research on Optimization of A Company's Agricultural Products Cold Chain Logistics System

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: Research on Optimization of A Company's Agricultural Products Cold Chain Logistics System

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The dissertation is a study of agricultural products cold chain logistics system, and the purpose is to establish a flexible ordering method to optimize costs and increase profits.

This dissertation first makes a theoretical analysis of cold chain agricultural product logistics, and compares with other product logistics to get the characteristics of cold chain agricultural product logistics: perishability, harsh preservation environment, and mutual incompatibility. Subsequently, the impact of COVID-19 on international cold chain transportation is analyzed, including the increase in freight costs and the need for virus testing after the arrival of the goods. The above factors will lead to rising costs and unstable supply of enterprises.

This dissertation subsequently established a flexible order quantity model, where suppliers and distributors agreed on a certain order quantity range, not just a fixed value. Suppliers and distributors bear different costs, and both transportation costs and inventory costs are considered in the costs (the two are contrary to each other). There are two strategies to choose from, either the transportation cost is borne by supplier or distributor. The objective function is to maximize the total profit of the supply chain.

Subsequently, the model was applied to a company in my country (Company A), operating Matlab to find the optimal order quantity and the corresponding cost, and performing sensitivity analysis on related parameters, so as to conclude that the transportation cost is better borne by the distributor.

KEY WORDS: Cold chain logistics, COVID-19, Flexible order quantity, Transportation cost, Inventory cost

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1.Introduction

1.1. Background and Significance

In recent years, competition among enterprises has become increasingly fierce. In order to obtain more income and higher profit margins, enterprises need to take control of various costs. At present, logistics costs are still account for a large proportion. In China, logistics industry is developing rapidly, and cold chain logistics, as an important part of logistics, has promoted the development of related industries. The demand for cold chain logistics has been increasing year by year, but the rapid development has also caused some problems, such as unreasonable cold chain logistics system design, high costs, and high losses during transportation.

As a branch of cold chain logistics, agricultural product cold chain logistics has its own unique characteristics. First of all, value of agricultural products are gradual declining over time. The quality of agricultural products gradually declines until they final decay (which means deterioration of the product), and the product no longer has value. The cold chain logistics of agricultural products needs to be delivered to the destination within a specific time frame, which requires high logistics timeliness. Secondly, the cold chain logistics of agricultural products has the harshness of the transportation environment. Due to the nature of different types of agricultural products, the cold chain logistics has high requirements for the storage environment. Most of them require a specific temperature range to be maintained throughout the process. Once the range exceeds the requirements, it will cause irreversible damage to the agricultural products, resulting in cargo damage. Sometimes there are also humidity requirements for the transportation environment. The last is the incompatibility of different types of goods. Conventional cargo has better compatibility, and there are fewer restrictions on cargo LCL loading. The cold chain logistics of agricultural products is mostly the same product or the same type of products being transported together. If different types of goods are transported together, it will lead to the consequences of agricultural products odor and premature maturity (for example, apples and kiwis cannot be transported together because the ethylene gas released by the apples will accelerate the ripening of the kiwis.), which will lead to the impairment of goods.

For the COVID-19 virus, a low temperature environment is an ideal environment for virus survival. Cold chain logistics products may carry the COVID-19 virus while being transported from one place to another. Therefore, in China, the customs requires virus testing for every batch of imported cold chain agricultural products. Sometimes one virus testing is not enough, some suspicious goods require multiple inspections and tests. This policy is beneficial to avoid the possible risk of import cargo with COVID-19 virus. But at the same time it has negative effect on the transportation of cold chain agricultural products, especially the transportation time.

1.2. Research Content and Purpose

This article considers that under the influence of COVID-19, which means under the condition of uncertainty in cold chain logistics transportation, taking the result (maximizing supply chain profit) as the guide, combining quantitative and qualitative methods, modeling and designing the cold chain agricultural product logistics system. This model is an optimization model and mainly considers two aspects, the uncertain lead time caused by the inspection of agricultural products and the deterioration and devaluation of agricultural products over time, both of which will have an impact on the total cost. Considering the above two aspects, in order to minimize the cost and maximize the profit, a new flexible delivery quantity model is designed. The transportation cost and inventory cost are simultaneously considered in the model, so as to ensure the profit of distributors and the increase of the total profit of the whole supply chain.

Subsequently, the model was applied to an agricultural product company in our city to prove the validity of this model. This article also includes the limitations of the model and possible future research directions.

1.3. Methodology

In the research process, the paper mainly uses the following method. The first part is about literature research method. Through a large amount of information, I learned about the characters of agricultural products cold chain logistics and the difference between cold chain logistic with others. Besides, models related to optimization of logistics system are collected and divided to several parts. These models can be used for reference.

The second part is about the quantitative analysis. Considering the impact of the above-mentioned COVID and agricultural products are easily consumable goods, a flexible ordering model is needed to ensure stable supply. The quantitative analysis involves three elements which are data collection, analysis and interpretation to do research purpose for the study. In terms of data collection, a combination of primary and secondary data is used. Part of the data comes from the company's internal sources, while other data is based on reasonable assumptions. In this study it applied the quantitative research method to find the best minimize total cost for company A. The quantitative model calculates and demonstrates through the knowledge of probability theory, and calculates the optimal quantity and cost through MATLAB software. Sensitivity analysis was also carried out to confirm the influence of some parameters on the model, with figures and graph to illustrate the conclusion and reasons and some corresponding suggestions are given to improve the total supply chain profit. The technology roadmap for this research is on Figure 1.

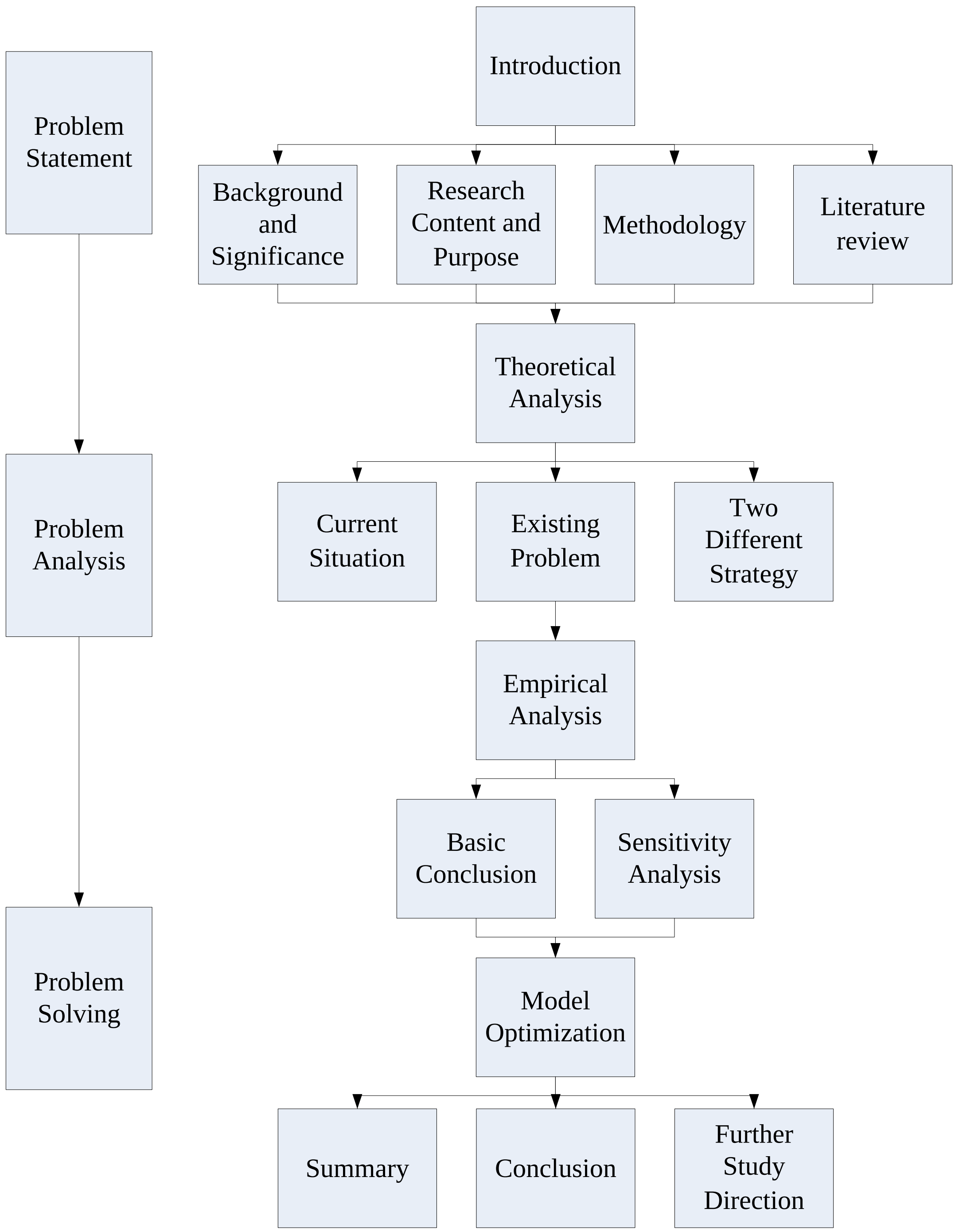

Figure1.Technology roadmap for research

2.Literature review

2.1. Cold Chain Logistics

Scholars and business operators have conducted extensive research on the system design of agricultural cold chain logistics. I found that it is important to develop cold chain logistics for agricultural product.

Mercier et al. (2017) explained that fruits and vegetable losses can be reduced through the improvement of cold chain logistics quality. Here, improvement refers to temperature range control and total transportation process monitor.

Rakesh et al. (2019) had a similar view, but analyzed it from the perspective of a third-party logistics company. Reliability and safety are the basic requirements of cold chain logistics. Only by meeting the above requirements can we obtain high customer satisfaction and profitability.

Bogataj et al.（2005）pointed out that only when the cold chain logistics is reliable enough can it increase consumer value and ensure the lowest cost. Here, reliable refers to both good quality and punctuality

Kamble et al.（2020）pointed out that data-driven logistics is the future development direction of agricultural product logistics. To continuously improve the logistics process through data analysis and achieve the goal of sustainable development

Wang et al.（2021）pointed out that a win-win situation should be created when designing the logistics system, not only considering the minimum cost, but also ensuring customer satisfaction.

2.2. Agricultural Products

There are also a lot of researches about the modal of algorithms and models related to agricultural cold chain logistics.

Chen et al. (2019) developed a formal mixed-integer linear program (MILP) and a descriptive model to solve a real-world case of cold chain distribution in the Yangtze River Delta of China.

Wu (2019) developed a quantified method to calculate the carbon footprint of the cold chain logistic and helping retailers to choose the most optimal cold chain scenario as well as package design to make their food supply chains more sustainable.

Eleonora (2019) not only considered cold chain logistics from the perspective of the smallest total cost, but also took CO2 emissions into consideration. The highest total cost and environmental impact are due to the product delivery process calculated by Microsoft Excel™.

Hsiao et al. (2018) considered vehicle routing, quality to the customer, temperature setting, and fleet size. Also established the last mile model of cold chain logistics for agriculture.

Chen et al. (2019) developed a new replenishment policy (with intelligent method) which simulated stochastic demand perfectly and the new method can help decrease total cost by 16.27%.

Rocco and Morabito (2016) analyzed the Brazilian tomato logistics was from the entire production process. During the period, the entire process of tomato from planting to maturity and finally converted to tomato sauce for sale was considered, rather than limited to a certain stage.

Taleizadeh et al. (2019) developed an inventory control model and calculated the optimal order quantity and out-of-stock quantity of perishable items.

Bozorgi et al. (2014) designed an inventory modal considering cost and emission.

They used a variety of parameter ratios to show the effectiveness of the proposed model.

Saif et al. (2016) designed a simulation-optimization approach modal. This model has two goals, which are the minimum total logistics cost and the minimum environmental impact.

Bozorgi (2016) designed a Multi-product inventory model. Compatibility with other products was considered in the inventory model. In this model, agricultural products are divided into several series. Numerical experiments demonstrate the solution procedure and effectiveness.

2.3. Literature Review Conclusion and Outlook

Summarizing and analyzing the above-mentioned literature, scholars mainly analyzed the cold chain logistics of agricultural products from two aspects of particularity and importance, and optimized the design through quantitative and modeling methods. These optimization designs mainly include one or more objective functions and several conditions (variables) to quantify the loss of agricultural products to obtain the optimal or better solution. Some literatures have specific analysis objects and use case analysis to analyze a certain region or a certain cold chain agricultural product. Some literatures have solved the optimal solution of the problem in a quantitative way, while others have optimized the existing situation to obtain a better solution. However, most of the above-mentioned researches do not consider the impact of random events and unexpected events on the cold chain of agricultural products (only Chen considers the randomness of demand). This aspect is an area that can be explored.

The above-mentioned literatures on cold chain logistics of agricultural products cannot bypass the two major characteristics of total cost and perishable agricultural products. The problem is modeled and solved through the setting of variables and the application of parameters and the establishment of several constraints. The total cost is subdivided into inventory cost, transportation cost and other costs. Related to inventory costs are mainly order quantity, order cycle, order quantity and safety stock management. EOQ is an important issue related to inventory model. The economic order lot model was first proposed by F.W. Harris in 1915. The model has the following assumptions：

(1) The demand rate is known and constant

(2) There is no maximum or minimum limit for one order quantity.

(3) There is no price discount for purchase and transportation.

(4) The order lead time is known and constant.

(5) The order fee has nothing to do with the order batch.

(6) The inventory maintenance fee is a linear function of inventory.

(7) The replenishment rate is unlimited, and all orders are delivered at one time.

(8) Out of stock is not allowed.

(9) Adopt a fixed volume system.

Also two following requirements:

(1) The item is replenished in batches, purchased or manufactured, and it is not produced continuously.

(2) The rate of sales or use is uniform and low compared to the normal production rate of the item, resulting in a significant amount of inventory.

There are many criticisms of the theory of economic batches, but they are not criticizing the insufficiency of the method in content, but criticizing the attitude of using this method indiscriminately and inappropriately regardless of the actual situation. In the book "Principles of Production Management", Professor Burbic's criticism of economic batches is roughly as follows:

(1) It is a reckless investment policy—the amount of investment is determined regardless of the amount of capital available.

(2) It forcibly uses an inefficient multi-stage ordering method, according to which all

parts are sufficient to be provided in different periods.

(3) It avoids the cost of preparation, let alone analyzes and reduces this cost.

(4) It is incompatible with the proven industrial management ideas of some successful companies.

Although there are some limitations and shortcomings in the EOQ model, this cannot prevent it from becoming the most classic model in the inventory ordering model. Later, many scholars modified and improved the EOQ model, so that they can be applied in different situations. The majority of scholars set different variables (such as out of stock, quantity discount, delayed delivery, random demand, etc.) in order to find the most suitable order quantity.

Another hot issue is the problem of vendor managed inventory (VMI). In this model, upstream suppliers own inventory, make plans, and coordinate retail and distribution, while downstream retailers provide data and keep inventory to quickly respond to user needs. The purpose of improving service levels and reducing inventory. This model is currently mainly used in fast-moving consumer companies that require rapid changes in demand and products that require rapid response. This model considers more of an overall supply chain, rather than just focusing on a certain node or part.

Also transportation costs are another important issue, it is mainly related to the choice of transportation methods (own logistics or outsourcing logistics also called 3rd part logistic), and the choice of transportation routes (usually referring to the shortest path problem and the related last-mile or shuttle delivery problem). Related popular models include vehicle routing model (VRP), and related variant models, including but not limited to VRP model with time window, VRP model with random demand, etc. When solving the VRP problem, usually the main objective function is the minimum cost (some special products such as military products or agricultural products that will decay over time, the objective function may become the shortest time or the highest profit). In addition, there are several constraints, such as time window, capacity limitation, one-way street limitation, node order restriction or incompatibility limitation (this limitation is more common in chemical products).

Algorithms to solve this problem range from the simplest saving path method to the complex ant colony algorithm, branch and bound method, and machine learning algorithm. Sometimes this problem is not to find the optimal solution, but to find an acceptable better solution.

Another hot issue is the location of equipment. For a multi-level supply chain (with multiple factories, warehouses, distributors, and retailers), the location of a facility is a problem worthy of discussion, and is related to it. The solution method is mainly Analytic Hierarchy Process (AHP) and the similar Fuzzy Analytical Hierarchy Procedure (Fuzzy AHP). Other costs involve some information sharing costs, opportunity costs, etc. The literature in this area mainly analyzes from the perspective of the overall supply chain, through the formulation of different strategies and the design of the supply chain to minimize the cost of, for example, the bullwhip effect.

The bullwhip effect is a common phenomenon in the supply chain. It refers to a phenomenon of demand variation and amplification in the supply chain. In the information flow, because information cannot be shared effectively, the information is distorted and amplified step by step, resulting in greater and greater fluctuations in demand information. The "bullwhip effect" is a common high-risk phenomenon in marketing. It is the result of the game between sellers and suppliers in demand forecast correction, order batch decision-making, price fluctuations, shortage game, inventory liability imbalance, and environmental variation. Increased the instability of suppliers' production, supply, inventory management and marketing. There are mainly the following ways to reduce this impact, including but not limited to

(1) Order classification management

(2) Strengthen warehousing management and reasonably share inventory responsibilities

(3) Gaming behavior in avoiding shortages

(4) Refer to historical data, reduce and correct appropriately, and send in batches

(5) Information sharing, shorten the lead time, and respond quickly

With the increasing awareness of environmental protection in various countries, CO2 emissions are a very hot topic. Some scholars not only considered economic benefits, but also considered social effects into their papers. These considerations mainly include the amount of carbon dioxide emissions, or the impact of this behavior on the local environment, employment and other conditions. Social benefits are usually not easy to judge good from bad through quantification. It is more qualitative analysis to determine whether the impact is positive or negative.

Based on the emergencies of COVID-19, this article has optimized the inventory design of a certain cold chain agricultural product in my country. Taking into account the inventory cost and transportation cost, the calculation determines the flexible order quantity.

3.Analysis of A company's agricultural product cold chain logistics system

3.1. Current situation of A company's agricultural products cold chain logistics

Company A is a cold chain agricultural product processing enterprise in my country. Its business is mainly to import raw materials and semi-finished products of cold chain agricultural products from overseas countries, and deliver the products to downstream sellers and distributors after processing, sub-packaging, and packaging on the production line. Sales are carried out by downstream subsidiaries. Company

A’s main products include but not limited to rice, flour, grains and oils, soybeans, tea, meat products and dairy products. In the transportation of these agricultural products, some need to be transported in dry bulk, while others are imported through cold chain containers. In recent years, with the growth of market demand, company A’s cold chain agricultural products are in a period of rapid development. Taking into account the characteristics of agricultural cold chain logistics, in order to ensure the continuous stability of production, avoid the occurrence of agricultural product corruption or failure due to long-term transportation. Stable lead time leads to unstable supply, which leads to disconnection of the production line. An ordering method with a certain degree of redundancy is necessary and effective. More flexible inventory strategies and ordering methods can effectively help A company improve the stability of the supply chain and reduce risks. The agricultural products considered in this article refer to the agricultural products of Company A that require cold chain transportation. A company's business flow chart is shown on Figure2.

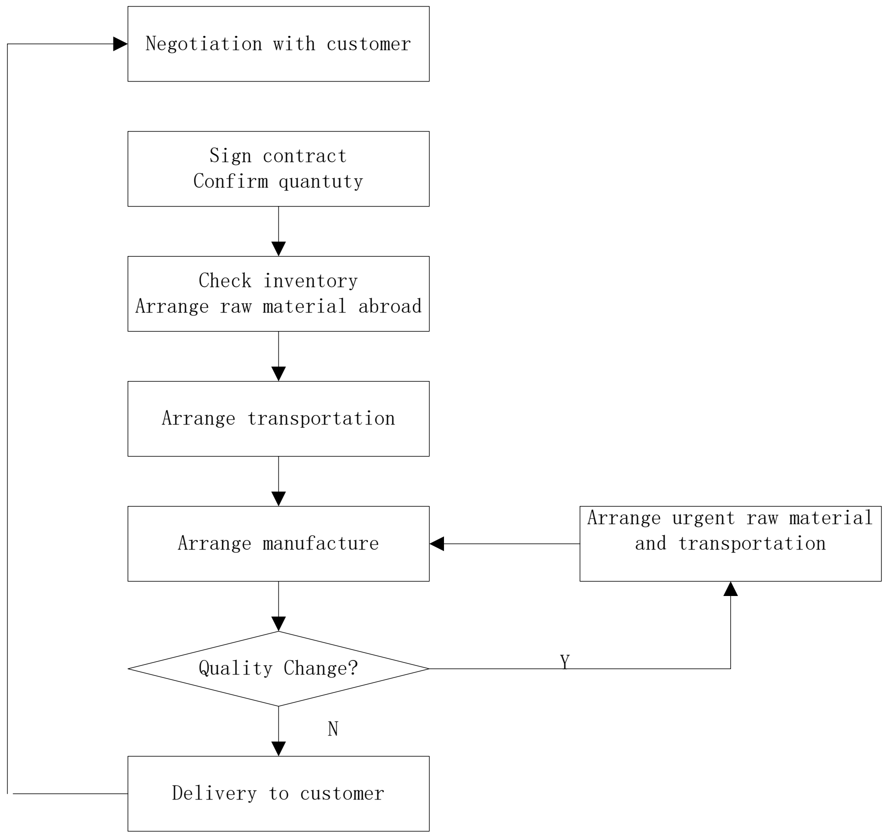

Figure2. A company's business flow chart

Taking into account both the cost and customer needs, the raw materials of company A's agricultural products are mainly imported through refrigerated containers. During transportation, the refrigerated container can create a suitable storage environment for agricultural products under normal circumstances, that is, maintain a certain temperature and humidity range, which will not allow the product to deteriorate or mature early (mainly fruits may mature early), and It will not cause the product to lose water or cause too much water to rot, so as to meet the needs of agricultural products preservation. To ensure the continuity of production, Company A will reserve a certain amount of safety stock both in raw material and product. This model is usually less costly and less risky. However, under certain special circumstances (such as the African swine fever virus infection in 2018), Company A will choose other raw material suppliers or place urgent orders from other raw material suppliers to ensure the normal operation of the production line.

In recent years, with the increase in global freight rates for refrigerated containers and the intensified delays in the arrival of overseas raw materials, Company A hopes to change the traditional delivery method so as to enhance the flexibility of the entire supply chain. Especially after the unpredictable event of COVID-19. First, COVID-19 has greatly reduced the timeliness and reliability of global container transportation. Secondly, because the COVID-19 virus is easier to survive at low temperatures, the customs of our country now needs to inspect and disinfect the goods in each batch of cold chain containers, which leads to the instability of the arrival and the increase of cargo damage. According to news reports from the General Administration of Customs of China, every batch of cold-chain goods imported into my country needs to be cleaned and disinfected strictly for internal and external packaging, storage sites, and production and processing equipment. When organizing or entrusting a qualified disinfection unit to perform disinfection, it shall ensure the disinfection effect while preventing secondary contamination of food. All cold chain goods need to be closed-loop management, that is, closed transportation from the ship to the port and finally to the warehouse, and cannot be in contact with other goods before being tested and confirmed, thereby reducing risks. Although my country has done full traceability and overall inspection for cold chain goods, there are still some batches of goods with COVID-19 virus on the outer packaging, which leads to poor delivery timeliness. This has led to a significant increase in the default risk of A company. Company A hopes to adopt a new flexible delivery method with downstream distributors, that is, the two parties agree on an specify range, and the distributor gives a minimum demand, so as to ensure the normal production of A company, while A company considers the loss and other conditions during production, and produces some more certain amount to ensure the order of downstream distributors. Company A tried this method with distributors, and encountered some problems during the entire project progress, including but not limited to: changes in freight costs caused by changes in freight, changes in costs caused by attempts to adjust the number of orders, and cost allocation.

Under normal circumstances, downstream distributors will often adjust the order quantity in order to ensure the health and reasonableness of their own inventory. This situation is very common in the actual operation of enterprises. Upstream and downstream enterprises encountering similar problems will try their best to meet supply needs through urgent orders. Therefore, for company A, the orders are divided into two types: regular orders and urgent orders. Distributors' urgent orders will bring a lot of costs to Company A. These costs mainly come from the urgent purchase of raw materials and urgent transportation, and sometimes the cost of production line plan adjustments. In the past, the transportation and procurement of cold-chain raw materials were more convenient. This emergency cost was not too much, and distributors were willing to pay for it. With the increase of international cold chain freight and transit time, the existence of urgent orders has become a problem. On the one hand, distributors are troubled by the higher cost, on the other hand, Company A is in trouble due to the instability caused by the increase in transit time. Inventory costs and transportation costs are always contrary to each other. If the inventory is kept in a small state, it is necessary to choose the fastest transportation method in case of emergency to ensure stable supply. Timely transportation represents high costs. On the contrary, if there is a certain amount of safety stock, you can choose a longer delivery time and cheaper freight when ordering. In the past, when transportation costs are low, it is feasible to have a lower inventory through urgent orders so as to get the minimize cost. At present, transportation costs are higher than before and transportation is unstable. Company

A needs to reconsider this problem and find a feasible way to solve this problem. The emergence of urgent orders will bring trouble to company A's operations, not only in the cost situation, but also in the complexity of the internal processes. Although A company has an internal system, this system will be troublesome for the above-mentioned situation that needs to change orders. This may bring about data statistics problems, which is not conducive to the formulation of related plans. A company also hopes to improve the system synchronously, and can more accurately record and archive the quantity of each demand. These data can be analyzed for reference, so as to facilitate more accurate confirmation of the number of orders in the future.

The impact of COVID-19 on global logistics and supply chains is continuous. The disruptions effects of COVID-19 will have a great impact on global companies, including but not limited to the risks of supply chain operations (unstable lead time) and the risk of supply chain disconnection (stopping of transportation leads to cessation of supply). For agricultural products that require cold chain transportation and have a short shelf life, the impact will be greater. In order to eliminate these effects, companies need to strengthen their supply chain resilience. Supply chain flexibility refers to the degree of flexibility of the supply chain, that is, the response of the supply chain when it encounters some emergencies or unexpected problems. When a supply chain with good flexibility encounters these problems, it will reduce or avoid the losses of the enterprise as much as possible, meet the operational needs of the supply chain, and ensure the service level and satisfaction of the downstream and end customers of the supply chain. Supply chain resilience is mainly composed of these three aspects, including supply chain design, supply chain operation, and supply chain recovery in case of emergencies. The former are pre-protective measures, and the latter two are remedial measures for problems that occur during actual operations. When designing the supply chain, it is necessary to consider some redundancy and safety measures, as well as several alternatives, so as to ensure the flexibility of the supply chain design. These security measures include, but are not limited to, multiple suppliers, multiple transportation methods, and multiple inventory management measures. In daily supply chain operations, it is necessary to do a good job of monitoring all linking nodes in the supply chain, and continuously optimize the whole process while considering the characteristics of its own products, so as to ensure the smooth operation of every part of the supply chain. The operation of the supply chain changes dynamically and in real time. During operation, it is necessary to continuously adjust the operation mode of the supply chain in real time and choose a reasonable supply chain strategy according to the external environment and internal operating conditions. When the supply chain is disconnected unexpectedly, we should respond as quickly as possible and apply some alternatives considered in the supply chain design to ensure the operation of the supply chain. If there is a problem at any node in the supply chain, the butterfly effect will cause the entire supply chain to be affected to varying degrees. The quicker it recovers, the less losses will be incurred.

The application of Industry 4.0 and Information technology can help improve the resilience of the supply chain. Company A is also aware of the importance of supply chain flexibility and hopes to improve the supply chain flexibility.

3.2. Existing problems of A company's agricultural products cold chain logistics

Although both A company and distributors (subsidiaries of A company) belong to the same group, the financial statements are calculated separately. When considering profits of products, they are based on their own perspectives. At present, there is still a situation that both sides only consider themselves, which leads to the situation that logistics and inventory costs are still high, and profits are low. Although company A tried to negotiate with distributors to adopt a flexible delivery method, due to lack of feasible data support, distributors usually still order a larger quantity of goods from company A in order to avoid inventory stock-out of their own, which led to company A’s situation that the cost control effect is not significant then predicted. On the other hand, in the confirmation of transportation costs, company A and distributors adopt a sharing method, which often leads to problems in freight calculation with urgent order. Company A and distributors hope to clarify who pays for the freight, so that both parties can maximize their profits.

At present, the order quantity of company A and distributors is mainly determined through negotiation. On this basis, company A takes into account the fragility of agricultural products and adds a certain margin for manufacturing. This status quo has led to sometimes high levels of raw material inventory of company A, and sometimes shortages of goods due to miscalculations by distributors, requiring company A to carry out emergency production, resulting in higher costs. Company A hopes to combine the historical order data of distributors to clarify the specific flexible delivery method in a more scientific way, so as to increase the profits of Company A and its downstream subsidiary distributors, so as to achieve the optimal decision of the supply chain and improve supply chain flexibility.

Company A has realized the importance of supply chain flexibility. In terms of supply chain design, supply chain operation and supply chain recovery, Company A has more or less problems or deficiencies. The first is the design of the supply chain. Although there are some redundant measures, these measures are not effective under the influence of COVID-19. These measures include, but are not limited to, multiple modes of transportation (cold-chain container shipping and cold-chain container multimodal transport), multiple refrigerated warehouses, and multiple sources of raw materials. The effect is not so good and mainly reflected in the high cost and low inventory turnover rate. Company A's supply chain is still not sufficiently redundant in the design of unexpected events, and needs to consider more possibilities to find corresponding preliminary solutions. The second is the supply chain operation. Company A can basically make the supply chain operate smoothly. However, because distributors and Company A still have certain problems in inventory management in order to protect their respective profits, there is still room for further optimization. Company A needs to try to negotiate and communicate with downstream distributors during operation and encourage them to share information, so as to think about the optimal direction of the overall supply chain, and construct a win-win situation for company A and distributors. Finally, in terms of supply chain recovery, because company A's inventory level is at a relatively high level, even in the period when COVID-19 has the most serious impact on global transportation, company A's supply chain still has no supply, but the cost is high. But this also makes A company aware of the existence of the problem and needs to make some pre-plans in this regard.

4.Optimal Model of Agricultural Products Cold Chain Logistics System

Taking the agricultural cold chain supply chain as the research object, a single supplier supplies a type of agricultural product to the distributor. In the supply chain, the distributor occupies a dominant position, and the supplier's decision is based on the distributor's decision. At the beginning of the order, the distributor determines the order quantity, and the supplier produces according to this quantity, but the quantity delivered by the supplier to the distributor has a certain degree of flexibility, thereby enhancing the flexibility of the supply chain. In the actual ordering phase, the supplier allows the retailer to place an order within a certain ordering interval. There is a minimum (the distributor's minimum order quantity) and a maximum (the supplier's maximum supply quantity). This interval is negotiated by both parties. Considering that the product supply of agricultural cold chain logistics is unstable, and the supply may fluctuate due to international transportation and deterioration of agricultural products, a new quantity flexible delivery strategy is adopted. Distributors order a certain number of products to ensure the supplier’s production. The production line can be produced normally, and the supplier produces a certain amount of products to ensure that the downstream orders meet their basic needs. In this strategy, the retailer’s profit is maximized as the goal to establish a model, and the upstream and downstream integrated supply chain is used as a reference. The optimal decision of the supply chain is considered when the freight is occupied by the supplier and the distributor respectively. The model also performs sensitivity analysis on related parameters. The supplier here refers to company A, and the distributor refers to the subsidiary company of company A, which is still represented by the distributor. Table 1 shows the costs borne by both parties, and who is responsible for the transportation cost has not been decided.

Table 1. Cost analysis table

	supplier	distributor
transportation cost	?	?
inventory cost	√	√
produce cost	√	X
out-of-stock cost	X	√
order cost	X	√

Note: The question mark represents the need to decide who is responsible for this cost, the tick represents the existence of this cost, and the cross represents the absence of this cost.

4.1. Model construction and parameter description

The conformance of the model is defined as follows,

C_1 Cost price per unit agricultural product of A company

C_2 The wholesale price of a unit agricultural product ordered by the distributor from Company A

C_3 The selling price of the distributor's unit agricultural product

q Distributor's order quantity, which is the decision variable

Q_1 The lower limit of the range of company A's delivery, that is, the distributor's minimum order quantity $Q_1 = (1-\beta)$ q

Q_2 The upper limit of the range of company A's delivery, that is, the maximum supply of company A $Q_2 = (1+\alpha)$ q

α Distributor's ordering upward adjustment ratio

β Distributor's ordering downward adjustment ratio

c_4 Distributor stock-out penalty cost

h_1 Company A's unit inventory cost

h_2 Distributor unit inventory cost

h_3 Transport cost per unit distance

L The distance between company A and distributor

λ The profit distribution factor between A company and distributor

π_1 π_2 π_3 Respectively represent the profits of Company A, distributors and supply chain when Company A bears the transportation costs

π_4 π_5 π_6 Respectively represent the profits of Company A, the distributors and the supply chain when the distributor bears the transportation cost

π_7 π_8 Respectively represent the profits of Company A and the distributors after the profit distribution when the distributor bears the transportation costs

In addition there are some following assumptions：

（1）The market demand x of the agricultural product is random and obeys a certain probability distribution, its density function is f(x), the distribution function of f(x)>0 is F(x),, $F(a)=\int_0^a f(x)dx$, Function mean is $u=E(x)=\int_0^\infty xf(x)dx$。F(x) is a continuously differentiable monotonically increasing function.

（2）$C_3 > C_2 > C_1 >> h_2 > h_1$， and the sales price is greater than the transportation cost which $C_3 > h_3 L$ The situation of these various costs is also in line with logical perception.

Then the entire supply chain of flexible order quantity is carried out in this way. The distributor and Company A analyze the historical sales quantity, and the two parties negotiate to determine the upper and lower adjustment range of the order quantity. The distributor gives the order quantity q, and company A organizes production and can provide up to $(1+\alpha)q$ products. Distributors allow flexible ordering within the scope of $[(1-\beta)q,(1+\alpha)q]$.

So let the distributor's expected sales volume when the order quantity is q be S(q), then

$$S(q)=\int_0^{(1+\alpha)q} xf(x)dx+\int_{(1+\alpha)q}^{+\infty}(1+\alpha)qf(x)dx=q(1+a)-\int_0^{(1+\alpha)q}F(x)dx$$

The distributor's expected order quantity in Company A is denoted by N(q), and the delivery interval is limited to between $Q_1=(1-\beta)q$ and $Q_2=(1+\alpha)q$

$$N(q)=\int_0^{(1-\beta)q}(1-\beta)qf(x)dx+\int_{(1-\beta)q}^{(1+\alpha)q} xf(x)dx+\int_{(1+\alpha)q}^{+\infty}(1+\alpha)qf(x)dx=S(q)+\int_0^{(1-\beta)q}F(x)dx$$

The distributor's expected inventory is represented by I(q). If the market demand x is less than the minimum order quantity Q_1= $(1-\beta)$ q , slow sales will occur and inventory cost exists.

$$I(q)=\int_0^{(1-\beta)q}[(1-\beta)\text{q-x}]f(x)dx=\int_0^{(1-\beta)q}F(x)dx$$

Correspondingly, the distributor's out of stock occurs when the market demand x is greater than Q_2= $(1+\alpha)$ q , and the out of stock cost occurs, with the out-of-stock quantity is L(q)

$$L(q)=u-S(q)=u-(1+a)q+\int_0^{(1+a)q}F(x)dx$$

Company A's end of period expected inventory is：

$$P(q)=\int_{(1-\beta)q}^{(1+a)q}[(1+a)\text{q-x}]f(x)dx+\int_0^{(1-\beta)q}[(1+a)\text{q-}(1-\beta)q]f(x)dx=\int_{(1-\beta)q}^{(1+a)q}\text{F}(x)dx$$

4.2. The situation when company A bears the transportation cost

In this strategy, company A provides a certain agricultural product to the distributor, and the distributor is allowed to be out of stock. Company A produces the agricultural product according to the initial order q given by the distributor, and company A does not have a stock out situation. The cost that Company A is responsible for consists of transportation cost, inventory cost and production cost. The costs borne by distributors include order costs, inventory costs, and costs in the event of stock-outs.

The distributor's expected profit at this time is

$$\pi_2 = c_3 S(q) - c_2 N(q) - h_2 I(q) - c_4 L(q)$$

$$= c_3[(1+a)q - \int_0^{(1+a)q} F(x)dx] -$$

$$c_2[(1+a)q - \int_0^{(1+a)q} F(x)dx + \int_0^{(1-\beta)q} F(x)dx]$$

$$-h_2[\int_0^{(1-\beta)q} F(x)dx]$$

$$-c_4[\mu - (1+a)q + \int_0^{(1+a)q} F(x)dx]$$

$$= (c_3 - c_2 + c_4)(1+a)q + (c_2 - c_3 - c_4)\int_0^{(1+a)q} F(x)dx - (c_2 + h_2)\int_0^{(1-\beta)q} F(x)dx - c_4\mu$$

In order to obtain the maximum expected profit of the above formula, it is necessary to determine the unevenness of the above profit function, so as to find the optimal order quantity. Find the first derivative with respect to q：

$$\frac{\delta \pi_2}{\delta q} = (c_3 - c_2 + c_4)(1+\alpha) + (c_2 - c_3 + c_4)(1+\alpha)[F(1+\alpha)q] - (c_2 + h_2)(1-\beta)F[(1-\beta)q]$$

Continue to find the second derivative with respect to q,

$$\frac{\partial^2 \pi_2}{\partial q^2} = (c_2 - c_3 - c_4)(1+\alpha)^2[f(1+\alpha)q] - (c_2 + h_2)(1-\beta)^2 f[(1-\beta)q]$$

due to $c_2 - c_3 - c_4 < 0$ and $(c_2 + h_2) > 0$，Therefore, f(x) is always greater than zero. And $\frac{\partial^2 \pi_2}{\partial q^2}$ is always less than zero，That is, π_2 is a concave function of q. When $\frac{\delta \pi_2}{\delta q} = 0$,there is q_1^* that maximizes the expected profit of the distributor. So

$$\frac{\delta \pi_2}{\delta q} = (c_3 - c_2 + c_4)(1+\alpha) + (c_2 - c_3 + c_4)(1+\alpha)[F(1+\alpha)q] - (c_2 + h_2)(1-\beta)F[(1-\beta)q] = 0$$

Therefore, after the distributor determines the order quantity, company A organizes production and transportation according to the distributor's order, and the transportation cost is borne by company A, then the expected profit of company A is

$$\pi_1 = c_2 N(q_1^*) - c_1(1+\alpha)\ q_1^* - h_1 I(q_1^*) - N(q_1^*)\ \alpha L$$

$$= (c_2 - \alpha L - c_1)(1+\alpha)\ q_1^* - (c_2 - \alpha L + h_1)\int_{(1-\beta)\ q_1^*}^{(1+\alpha)\ q_1^*} F(x)dx$$

Let the sum of the above two formulas (the expected profit of the distributor and the expected profit of A company) be the expected total profit of the supply chain. The expected profit of the entire supply chain is:

$$\pi_{3.} = \pi_1 + \pi_2 = (c_3 - \alpha L - c_1 - c_4)(1+\alpha)\ q_1^*$$

$$-(c_3 + c_4 + h_1 - \alpha L)\int_0^{(1+\alpha)\ q_1^*} F(x)dx$$

$$+(h_1 - \alpha L - h_2)\int_0^{(1-\beta)\ q_1^*} F(x)dx - \mu c_4$$

At this time, when company A bears the transportation cost, the distributor is not restricted by the transportation cost when determining the optimal order quantity. At this time, there is still room for optimization in the supply chain, so further optimization is needed.

4.3. The situation when distributor bears the transportation cost

At this time, company A is responsible for inventory costs and production costs, and distributors are responsible for inventory costs, out-of-stock costs, ordering costs, and transportation costs.

The distributor bears the transportation cost, and its expected profit model is

$$\pi_5 = c_3 S(q) - c_2 N(q) - h_2 I(q) - c_4 L(q) - N(q)\alpha L$$

$$= (c_3 + c_4 - c_2 - \alpha L)(1+\alpha)q + (c_2 + \alpha L - c_3 - c_4)\int_0^{(1+\alpha)q} F(x)dx - (c_2 + h_2 + \alpha L)\int_0^{(1-\beta)q} F(x)dx - \mu c_4$$

The first item is the sales revenue of the distributor, the second item is the ordering cost, the third item is the inventory cost, the fourth item is the cost when the stock is out of stock, and the last item is the transportation cost borne by the distributor.

Find the first derivative of the above formula with respect to q,

$$\frac{\partial \pi_5}{\partial q} = (c_3 + c_4 - c_2 - \alpha L)(1+\alpha) + (c_2 + \alpha L - c_3 - c_4)[F(1+\alpha)q] - (c_2 + h_2 + \alpha L)(1-\beta)[F(1-\beta)q]$$

Continue to find the second derivative to get

$$\frac{\partial^2 \pi_5}{\partial q^2} = (c_2 + \alpha L - c_3 - c_4)(1+\alpha)^2[f(1+\alpha)q] - (c_2 + h_2 + \alpha L)(1-\beta)^2[f(1-\beta)q]$$

Observe the previous formula, and $(c_2 + \alpha L - c_3 - c_4 > 0$ also $(c_2 + h_2 + \alpha L) > 0$,

Because f(x) is always greater than zero, the first term in the above formula is less than zero, and the latter term is always less than or equal to zero. So the second derivative with respect to q is always less than zero, that is, π_5 is a concave function with respect to q. At this time, there is an optimal order quantity q_2^* to maximize the expected profit of the distributor, The optimal order quantity can be obtained when $\frac{\partial^2 \pi_5}{\partial q^2} = 0$.

At this time, the expression of expected profit of A company is

$$\begin{aligned}
\pi_4 &= c_2 N(q_2^*) - c_1(1+\alpha)q_2^* - h_1 I(q_2^*) \\
&= (c_2 - c_1)(1+\alpha)q_2^* - c_2[\int_0^{(1+\alpha)q_2^*} F(x)dx] - \int_0^{(1-\beta)q_2^*} F(x)dx - h_1 \int_{(1-\beta)q_2^*}^{(1+\alpha)q_2^*} F(x)dx \\
&= (c_2 - c_1)(1+\alpha)q_2^* - (c_2 + h_1) \int_{(1-\beta)q_2^*}^{(1+\alpha)q_2^*} F(x)dx
\end{aligned}$$

So when the order quantity is q_2^*, the corresponding supply chain expects the total profit $\pi_6 = \pi_4 + \pi_5$

If $\pi_6 > \pi_3$, it means that when the distributor bears the transportation cost, the expected total profit of the supply chain is increasing (subsequent numerical calculation examples will prove it). But at this time, compared with the transportation cost borne by A company, the expected profit of distributors has decreased, while the expectation theory of A company has increased. At this time, in order to encourage the distributors to accept this suggestion, Company A may use a specific profit distribution strategy to distribute the profits to the distributors in a certain proportion, so as to ensure that the expected profits of both parties will rise and achieve a win-win situation.

At this time, through the profit distribution factor λ, assuming that the two parties distribute according to a certain percentage of increased profits, the increased profit of A company is $\Delta\pi = \pi_4 - \pi_1$, where $\Delta\pi * \lambda$ is distributed to the distributor, and the distributor's expected profit after distribution is $\Delta\pi_1 + (1-\lambda)\,\Delta\pi$, and the expected profit of A company is $\pi_5 + \lambda\Delta\pi$. If $\Delta\pi_1 + (1-\lambda)\,\Delta\pi > \Delta\pi_1$ and $\pi_5 + \lambda\Delta\pi > \pi_5$, both parties expect profits to increase.

If $\pi_6 \le \pi_3$, this strategy is not required and maintain original status.

5.Case study

5.1. Data collection

Based on the above analysis, a quantitative research method is used to determine the existence of the optimal order quantity and the effectiveness of the expected profit change for the entire supply chain. Through the sensitivity analysis of the parameters and showing them in the chart, it is determined that the parameters for the three models (Company A bears the transportation cost, the distributor bears the transportation cost, and the distributor bears the transportation cost and distributes the profit) is the optimal order quantity and The impact of supply chain profits, so as to make it clear that distributors bear transportation costs will be more conducive to cost optimization.

According to the historical data fitting of a certain product, the market demand of this product conforms to the normal distribution of $X \sim N(1000, 60^2)$, The parameter values of the remaining prices are established according to the average value of historical data. and the values of other parameters are shown in Table 2.

Table 2. Parameter value

c_1	c_2	c_3	c_4	h_1	h_2	h_3	L	α	β	λ
115	240	400	5	10	15	0.2	100	0.2	0.2	0.01

5.2. Model solving

According to the above-mentioned data, the result of the model is obtained using the MATLAB compilation environment. The goal is to maximize the profit, so as to determine the quantity of each order and the related profit situation. The integral part is realized by the convolution function.

Table 3. Experimental results

q_1^*	q_2^*	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8
1000	998	80000	160000	240000	100300	140000	240300	160097	80203

5.3. Parameter sensitivity analysis

For h_3, the unit transportation cost per unit of commodity. Using 0.1 as the step size, change from 0.1 to 1.0 to get the results in the following table:

Table 4. The influence of parameter h_3 on the optimal solution of the model

h_3	q_1^*	q_2^*	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8
0.1	1000	999	85200	160000	245200	100150	150000	250150	164800	85350
0.2	1000	998	80000	160000	240000	100300	140000	240300	160097	80203

0.3	1000	997	65600	160000	225600	100450	130000	230450	164501	65949
0.4	1000	996	55800	160000	215800	100600	120000	220600	164352	56248
0.5	1000	994	46000	160000	206000	100750	110000	210750	164202	46548
0.6	1000	993	36200	160000	196200	100900	100000	200900	164053	36847
0.7	1000	992	26400	160000	186400	101050	90000	191050	163903	27147
0.8	1000	991	16600	160000	176600	101200	80000	181200	163754	17446
0.9	1000	989	6800	160000	166800	101350	70000	171350	163604	7746
1.0	1000	987	-3000	160000	157000	101500	60000	161500	163455	-1955

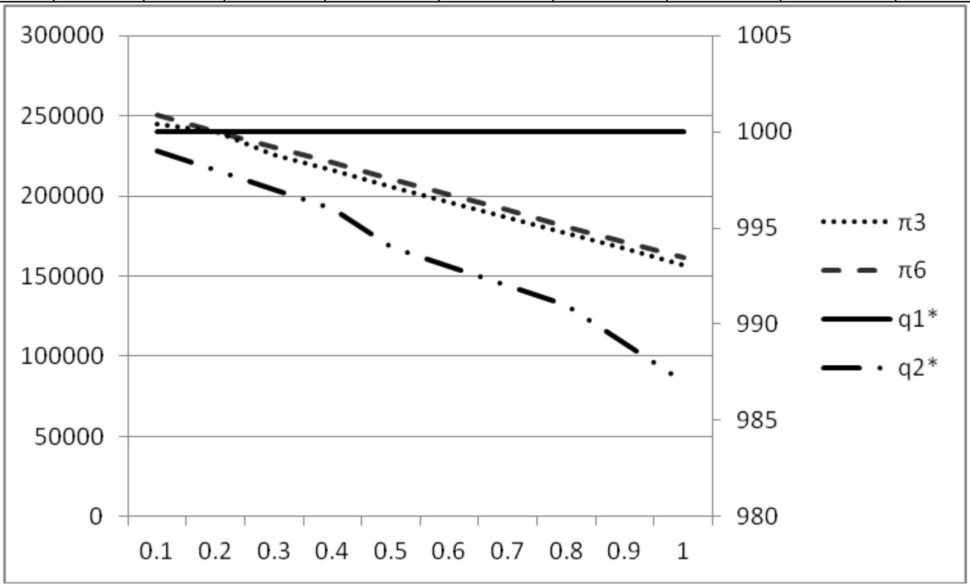

Figure3. The influence of parameter h_3 on the optimal solution of the model

Similarly, for β , the distributor’s ordering downward adjustment ratio. Using 0.1 as the step size, change from 0.1 to 1.0 to get the results in the following table:

Table 5. The influence of parameter β on the optimal solution of the model

h_3	q_1^*	q_2^*	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8
0.1	951	949	87350	160000	247350	107650	140000	247650	160097	87553
0.2	1000	998	80000	160000	240000	100300	140000	240300	160097	80203
0.3	1053	1052	72050	160000	232050	92200	140000	232200	160008	72193
0.4	1113	1111	63050	160000	223050	83350	140000	223350	160097	63253
0.5	1179	1178	53150	160000	213150	73300	140000	213300	160011	53339
0.6	1225	1225	46250	160000	206250	66250	140000	206250	160000	46250
0.7	1250	1250	42500	160000	202500	62500	140000	202500	160000	46250
0.8	1250	1250	42500	160000	202500	62500	140000	202500	160000	46250

0.9	1250	1250	42500	160000	202500	62500	140000	202500	160000	46250
1.0	1250	1250	42500	160000	202500	62500	140000	202500	160000	46250

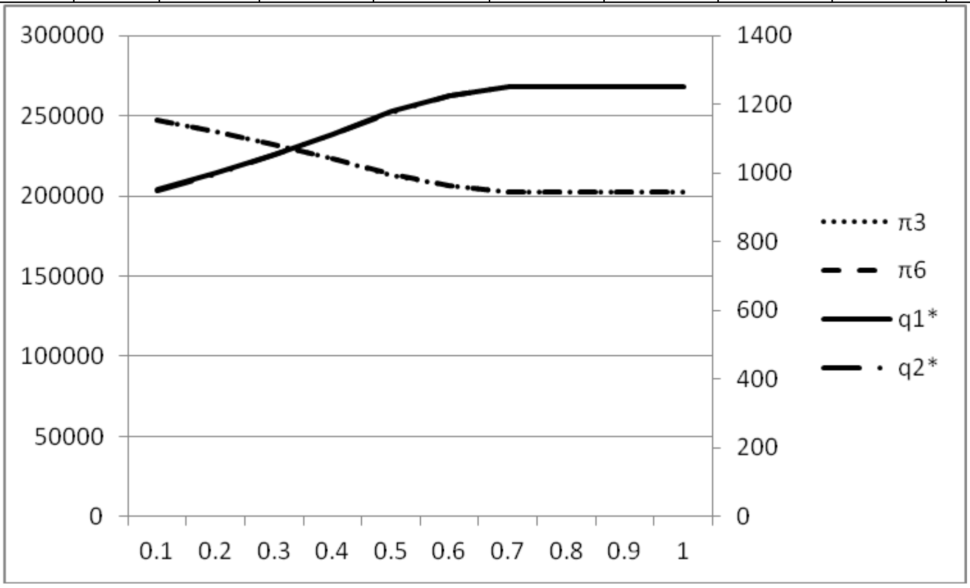

Figure4. The influence of parameter β on the optimal solution of the model

Similarly, for α , the distributor's ordering downward adjustment ratio. Using 0.1 as the step size, change from 0.1 to 1.0 to get the results in the following table:

Table 6. The influence of parameter α on the optimal solution of the model

h_3	q_1^*	q_2^*	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8
0.1	1051	1049	85488	160000	245488	105763	140000	245763	166072	85691
0.2	1000	998	80000	160000	240000	100300	140000	244030	160097	80203
0.3	952	951	75264	160000	235264	95463	140000	235463	160013	75460
0.4	910	909	70750	160000	230750	90925	140000	230925	160011	70914
0.5	871	870	66688	160000	226688	86875	140000	226875	160005	66870
0.6	834	834	63200	160000	223200	83200	140000	223200	160000	63200
0.7	800	800	60000	160000	220000	80000	140000	220000	160000	60000
0.8	771	770	56525	160000	216526	76750	140000	216750	160014	56736
0.9	742	741	53775	160000	213775	74013	140000	214013	160035	53987
1.0	716	715	51000	160000	211000	71250	140000	211250	160047	51203

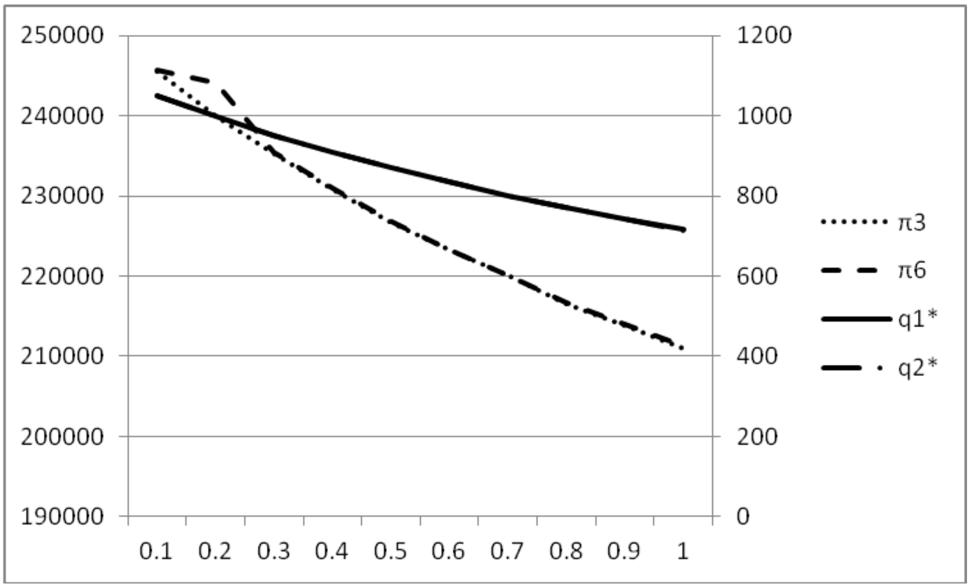

Figure5. The influence of parameter α on the optimal solution of the model

5.4. Conclusion and recommendation

According to the calculation of the above historical values, this new flexible order quantity model has proven to be effective, which can help companies reduce costs while increasing profits. Similarly, the setting of freight rates and up-down coefficients will affect the number of orders and the total cost. , The total profit has an impact. The following will briefly analyze how each of these three influences the number of orders, total cost and total profit, and how company A responds to these influences, so as to gain a more active position for itself.

The expected profits in Table 4 are displayed in the form of a line chart, which more intuitively shows the influence of the parameters h_3 on both parties in the supply chain and the entire supply chain in the model.

When company A bears the transportation cost, as the unit transportation cost rises, the distributor's order quantity and expected sales profit will not change accordingly, while the expected profit of company A will decrease with the increase in transportation cost, until finally a loss occurs. When the transportation cost is borne by the distributor, the increase in transportation cost forces the distributor to reduce the order quantity, and the expected profit will also decrease. However, the expected profit of Company A shows an increasing law.

The expected total profit of the supply chain when company A bears the transportation cost is always less than the expected total profit when the distributor bears. It can be seen that distributors to bear the transportation costs can help the design optimization of the entire supply chain.

Similarly, distributors and company A can also reduce costs by selecting appropriate means and methods of transportation (such as multimodal transportation, etc.), using reasonable loading methods to make full use of space to reduce costs, or outsourcing the entire transportation business at a single price thereby optimizing transportation costs and reducing risks.

Similarly, Tables 5 and 6 respectively show the change in order quantity and corresponding cost when the uplink and downlink coefficients are changed.

When α changes from 0.1 to 1, the optimal order quantity in the model shows a downward trend, and the magnitude is roughly the same. Regardless of whether company A or the distributor bears the transportation costs, the change in α has no effect on the expected profit of the distributor, and will only reduce the expected profit of the company A. This is because the larger the α, the company A needs to produce more products to ensure downstream supply, which leads to an increase in production costs and inventory costs, and ultimately leads to a reduction in expected profits.

When company A bears the transportation cost, the distributor’s expected profit is always higher than the distributor’s expected profit to bear the transportation cost, while the expected profit of the company A is vice versa. Therefore, it is recommended that the setting of parameter α is coordinated by both parties to obtain that the total profit of the supply chain when the distributor bears the transportation cost is always higher, that is, the decision makers of the order lot bear the transportation cost to help optimize the supply chain.

Therefore, with the increase of α, the expected profit of A company gradually decreases, and the expected profit of distributors remains unchanged. Therefore, when A company confirms the upward coefficient α, it should take the initiative as much as possible to ensure the maximization of benefits. Of course, the upward coefficient a cannot be too small, otherwise the stability of the supply chain cannot be guaranteed. The author thinks that the upward coefficient 0.2 is an acceptable choice.

Correspondingly, when β is from 0.1 to 1, the optimal order quantity in the model shows an upward trend and the magnitude is roughly the same. Regardless of whether company A or the distributor bears the transportation costs, the change of β has no effect on the expected profit of the distributor, and will only reduce the expected profit of company A (company A must produce more products). When the distributor bears the transportation cost, the expected total profit of the supply chain is greater than when the company A bears the transportation cost.

The conclusion is similar to the coefficient α, that is, the increase of β will not affect the profit of the distributor, but it will cause the profit of A company to decrease. When company A negotiates with distributors, β cannot be too large, because it will affect company A's profits, but b cannot be too small, because that will greatly reduce the stability of the supply chain. The author thinks that the downward coefficient 0.2 is an acceptable choice.

The measure of profit sharing is feasible, and it can enable Company A and distributor to achieve a win-win situation. When the total profit of the supply chain is optimal, the profit of distributors is not optimal. For suppliers, in order to achieve the overall optimization of the supply chain, so that both distributors and suppliers can benefit from the new ordering strategy and achieve win-win status, profit distribution is a very effective and direct mechanism. The profit distribution method selected in this article is proportional distribution, and there are other methods such as distribution according to sales quantity, stepwise distribution (to meet a certain number, distribute a certain profit), and one-off profit distribution (according to the negotiation between the two parties). One value is used for profit distribution at one time). In actual operation, suppliers can also choose other ways to distribute profits with distributors, so as to encourage them to build the best ordering method for the supply chain together. Through this incentive measure, distributor will be more willing to choose a suitable order quantity, so as to achieve the best of the entire supply chain rather than only one part of the supply chain.

All of the above are based on overall supply chain considerations. This strategy adopts a flexible ordering strategy in the design, which can improve the design of the supply chain and also help reduce the cost of supply chain operations. Although it is not directly designed to restore the supply chain, flexible order quantities can give downstream distributors the greatest flexibility when the supply chain is broken, and to a certain extent also accelerate the restoration of the supply chain. Therefore, the above-mentioned strategy can improve the elasticity of the supply chain, thereby enhancing the A company's supply chain anti-risk ability, reducing costs and increasing profits in an unstable global environment.

In addition, it should be noted that this model is dynamic when applied, because the demand for goods changes, and both parties need to adjust the relevant data in time based on the changes in the demand for goods, so as to obtain a more suitable order quantity and a lower total cost, also a higher profit.

6.Summary

6.1. Conclusion and research deficiencies

In this research, based on a large number of literature studies and considering the actual situation of the enterprise, a joint optimization model of inventory transportation considering the flexible delivery quantity is established. The model takes the transportation cost borne by the supplier and the transportation cost borne by the distributor, and takes the highest expected profit of the distributor as the decision goal to find the optimal order quantity, and then finds the expected profit of the supplier and the expected total profit of the supply chain. The model was applied to an actual case in our country, using Matlab to calculate the actual value to find the optimal order quantity and the corresponding expected profit. Subsequently, a sensitivity analysis of the parameter transportation cost was made and relevant conclusions were drawn. Since the distributor's expected profit is the highest goal, when the transportation cost is borne by the supplier, there is no contradiction between the transportation cost and the inventory cost. When the distributor bears the transportation cost, the order quantity is constrained by the inventory cost and transportation cost, which is more conducive to the overall optimization of the supply chain.

Through the sensitivity analysis of transportation costs, the increase in transportation costs can reduce the expected total profit of the supply chain. Therefore, when affected by black swan events such as COVID-19, transportation costs should be reduced as much as possible, and distributors should be responsible for the transportation cost so as to ensure that the entire supply chain obtains more profits and solves the problem of efficiency contradictions.

This article also analyzes the flexible delivery quantity. The flexibility here is reflected by the upward and downward coefficients. It is not that the more flexible (that is, the larger the coefficient) is, the better. If the coefficient is too large, the total profit of A company and the supply chain will decrease. If it is too small, there will still be a large number of out-of-stocks and urgent orders, which will lead to unstable delivery and lose the meaning of flexible delivery.

There are still some shortcomings in the research of this article, and they can be used as the direction of future research.

6.2. Further research directions

From the complexity of the agricultural products cold chain logistics and the constraints of transportation, there are several research directions below that can be in-depth.

(1) Supply chain inventory transportation optimization problem with more complex results. The supply chain profit optimization in this article only realizes the optimization of part of the supply chain links. The actual supply chain of an enterprise has many subjects and complex links, and it also needs to consider customers, so as to realize the optimization of the multi-level supply chain. This article studies the supply chain model in the case of single supplier and single distributor. Situations involve one-to-many and many-to-many supply chains can be studied.

(2) The agricultural products cold chain supply logistics of random market demand is considered in this article. However, in reality, the agricultural products cold supply chain usually coexists with definite demand and random demand. Both issues are equally important and worthy of discussion. In the future, the related supply chain problems under the condition of both random and deterministic demand are worth

studying.

(3) The combined problem of inventory transportation of vehicle transportation capacity. This paper did not consider the limitation of vehicle carrying capacity and the corresponding inventory in transit in the research room. In actual situations, the limitation of vehicle carrying capacity and in-transit inventory are issues worthy of study. In the future, the limitation of vehicle carrying capacity can be integrated into the joint optimization problem of inventory transportation. .

(4) In order to simplify the calculation process, only the most important cost was considered when constructing the supply chain cost. In reality, there are still many costs associated with the supply chain. In order to reduce the impact of the bullwhip effect on the supply chain, companies often choose to share information, including information sharing in information systems or inventory. Therefore, in future research, the cost of information sharing can also be put into the model as a cost to clarify and quantify the impact of information sharing on inventory, lead time and costs in the supply chain.

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