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Optimization of Cold Chain Path forS company of C city based on Dijkstra's Algorithm

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Abstract

With regard to the existing transportation means and distribution routes of S company of C city, this paper analyzes them in terms of theoretical optimization and practical significance, aiming to reduce the cost of cold chain transportation. To this end, we determined the objective function of cold chain route optimization forS company of C city. Then, Dijkstra's algorithm is used to solve the cold chain routes. Combined with the example analysis results show that the optimization results based on Dijkstra's algorithm are reasonable and reliable. In this paper, based on the location information of S C city's stores and transit centers, as well as various data of distribution, respectively, the path optimization is carried out to ultimately achieve cost reduction and efficiency. Compared with the data of the original distribution method, both the use of transportation tools, distribution distance, and the problem of high empty rate have been improved.

Keywords

Cold Chain; Path Optimization; Cost Reduction; Dijkstra's Algorithm.

1. Introduction

1.1. Background of the Study

With the development of today's society, technology is more and more developed, people's quality of life is getting higher and higher, frozen goods in people's lives more and more occasions, the cold chain logistics industry has also been rapid development. However, due to the strict requirements for the distribution of frozen food, the existence of high cost of refrigerated transportation and loading and unloading, low utilization rate of vehicles, etc., enterprises have to spend a lot of manpower, material and financial resources in the process of distribution, so the distribution of frozen food needs to be paid extra attention to the link. If the logistics route for frozen goods can be reasonably planned, not only can save time and reduce costs for the enterprise, but also to ensure that the frozen food is delivered to the customer side of the high quality.

1.2. Purpose and Significance of the Study

Cold chain is currently developing rapidly, characterized by strong demand but high operation cost. By analyzing the product types and logistics path of S company of C city, including studying the characteristics of cold chain transportation and the theoretical knowledge related to the optimization of cold chain logistics path, combining with the study of the cold chain product distribution path of S company of C city and optimizing the adjustment, the logistics cost can be greatly reduced for the enterprise, so as to put the capital in a more suitable position, and at the same time, improve the efficiency of the transportation, and solve the problems of transportation time, not only to improve the core competitive advantage of the company in C city through time reduction, but also to rely on the reduction of equipment in exchange for more

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funds. The company can not only improve its core competitive advantage in C city by shortening the time, but also rely on the reduction of equipment in exchange for more funds. Combined with the status quo of cold chain transportation in C city and the development of the industry, and in the context of the construction of C city as an international first-class modern integrated food logistics center, the consolidation of S company of C city's strategic positioning as a leading enterprise of the frozen transportation industry in Sichuan Province is of certain practical and economic significance.

1.3. Content of the Study

In order to solve the cold chain pathway problem in S C city, this study focuses on the following key points:

1) To analyze and study the problem of cold chain express delivery from transit distribution centers to stores;

2) Establish the transportation route model of S logistics and distribution center;

3) Design the distribution path solving algorithm fromS company of C city's transshipment center to the outlet post;

4) Perform algorithm validation and solve practical problems in S C city;

Finally, the designed algorithm is used to solve the actual distribution problem of S company of C city, propose a reasonable distribution path, and verify the feasibility of the optimized path.

2. Literature Review and Overview of Theories Related to the Study

2.1. Literature Review

Academics have conducted in-depth discussions on cold chain logistics from transportation routes, warehousing, service levels, transportation equipment, etc.Songyi Wang[1] (2018) In order to optimize the fresh food logistics and distribution system with the optimization objective of minimizing the overall cost, a green, low-carbon, path selection problem (LRP) model for cold chain logistics considering carbon emission is constructed. To address this problem, a genetic algorithm based on heuristic rules is proposed in order to develop a green and environmentally friendly site selection and distribution scheme for cold chain logistics enterprises.Jun Qiao et al.[2] (2019) planned the actual routes of the vehicles in order to facilitate dealers to manage the vehicle distribution process, to keep abreast of the en route information, and to realize the visualization management function.Caihong Xiang et al.[3] (2020) introduced the definition and current situation of cold chain logistics. On this basis, a cold chain route allocation method based on time consumption is proposed. Based on this, the ant colony optimization[7] method and how to obtain the real delivery time are introduced. Finally, a distribution path optimization method based on delivery time and ant colony algorithm is proposed. Experiments show that the method can realize the optimal solution effectively.Ning Tao[4] (2021) For the problem of high carbon emission in cold chain logistics, the optimization method of fresh agricultural products cold chain logistics path based on carbon tax is studied. On this basis, the role mechanism of carbon tax policy is quantitatively studied with the total carbon cost and total cost as the optimization objective.Jian Wang (2022)[5] The cold chain logistics path optimization problem with time window is proposed and solved by genetic algorithm. By solving it, the optimal cold chain trucking path can be obtained to reduce the distribution cost. pan et al.[6] (2022) aims to minimize the cost of fresh produce cold chain logistics and distribution companies, considering all the costs such as vehicle loss, transportation, cargo damage, cold storage, and delay. An improved ant colony algorithm was used to solve the model, and examples were verified to provide a reference for the optimization decision of cold chain logistics and distribution paths.Lu et al.错误!未找到引用源。 (2023) defined the intercity carpooling path optimization problem with time window. Based on the

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balance of interests among passengers, platforms, and government, a multi-objective function is constructed with the objectives of minimizing passenger costs, maximizing platform revenue, and minimizing carbon emission costs, and constraints are imposed on the number of passengers carried, boarding and alighting points, and vehicle services. Secondly, in order to further improve the coordination ability and search speed of the operator, particle swarm optimization algorithm is used to help the operator remember the previous search position and iteration information, and PSO (particle swarm optimization) improved NSGA-II (non-dominated sorting genetic algorithm[8]) algorithm is designed to solve the multi-objective model.

2.2. Vehicle Path Problems

Vehicle Path Problem[9] means that the transit center owns a certain number of store stations that need to deliver a certain amount of goods, and in order to distribute cold-chained express shipments, the center arranges a specific number of vehicles and organizes suitable operation routes. In order to meet the demand and quantity of goods, the center needs to allocate vehicles and plan routes according to the situation. According to the different types of constraints of the VRP problem, it is mainly categorized into the types in Table 1:

Table 1. VRP Problem Classification

restrictive condition	Classification type
Number of distribution centers	Single distribution center, multiple distribution center issues
time constraint	Problems with time windows, problems without time windows
Optimize the number of targets	Single-objective problems, multi-objective problems
Delivery method	Self-supporting logistics, third-party logistics, and coordinated distribution issues
Distribution environment status	Static problems, dynamic problems
Distribution vehicle type	Single-vehicle model problem, multi-vehicle model problem

2.3. Multi-objective Optimization

A multi-objective optimization problem[10] is a problem where multiple metrics or objectives need to be considered in solving a given problem, which may be linked or constrained by each other and need to be combined and weighed to achieve the best overall result. Often, these objectives have different weights and need to be combined to achieve a balance. The mathematical form is described below:

$$\min Y=y(x)=[y_1(x),y_2(x),\ldots y_n(x)]\,(n=1,2,3,4,\ldots.n) \tag{1}$$

$$s.t.\, u_i(x)\le 0 \quad i=1,2,3,4,\ldots.n \tag{2}$$

$$v_j(x)\le 0 \quad j=1,2,3,4,\ldots.n \tag{3}$$

$$x=x_1,x_2,x_3,x_4,\ldots.x_n \tag{4}$$

$$x_{min}\le x_a\le x_{max} \quad a=1,2,3,4,\ldots\ldots n \tag{5}$$

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2.4. Principles of Dijkstra's algorithm

Dijkstra's algorithm[11] is an algorithm for solving shortest paths in a weighted graph. It is fundamentally guided by the idea of taking the start node as the beginning and gradually determining the shortest path to each node until the end node is reached.

In the application of the real problem, in the path network graph that describes the shortest path problem for the delivery of cold chain delivery vehicles, each node is given a labeled number (a-n,b-n). And each labeled node represents a different store post on the path network graph. The shortest delivery route length of the cold chain express transportation route from the starting s point to the node n can be represented by the serial number connection. The shortest route length of the shortest express delivery route from the starting point s to the point n in front of the point n in the shortest express delivery route from the starting point s to the node n. The shortest route length from the node to itself is denoted by 0. In the route labeling, if no transportation vehicle runs the route, the distance is inf (infinity).

2.4.1. Algorithm Selection Rationale

Dijkstra's algorithm has the following advantages in cold chain path optimization:

1) Able to consider the time window: in cold chain logistics, delivery time is very important. dijkstra's algorithm can calculate the optimal path according to the time window limit. This means that the deliveryman can deliver the items to the specified location within the specified time, thus improving the delivery efficiency.

2) Can improve the transportation efficiency: in cold chain logistics, the shorter the transportation time of the item, the better its quality. The use of Dijkstra's algorithm can quickly find the optimal path and reduce the time and cost of transporting items.

3) Can reduce costs: using Dijkstra's algorithm for path planning, can avoid excessive repetitive driving, thus reducing transportation costs. In addition, the algorithm is also able to avoid, to a certain extent, the loss of time and cost caused by traffic congestion and other reasons.

4) The algorithm is efficient: Dijkstra's algorithm finds the shortest path by constantly updating the value of the label. The algorithm has the advantage of being fast and accurate, which means that the calculator is able to realize finding the shortest path in a shorter time.

Therefore, Dijkstra's algorithm has obvious advantages in cold chain path optimization, which can improve the delivery efficiency, ensure the quality of items and reduce the transportation cost.

3. S C city Company Cold Chain Distribution Status Analysis and Problems

3.1. S C city's Cold Chain Business Introduction

S C city's cold chain business serves the local e-commerce, retail, distribution, and factory manufacturing segments. And it provides customized packaging for customers with an early warning monitoring system for humidity anomalies, equipped with warehouse temperature and humidity monitoring, high energy storage refrigerant temperature control technology, and connected to the GROUND land transportation resources trading platform, real-time monitoring system for on-board temperature control and intelligent global positioning of vehicles. Meanwhile, it is closely connected with the cold chain network of Head Office S to provide users with high-efficiency and high-quality logistics services.

3.2. S C city Cold Chain Transportation and Distribution Characteristics

As a leading company in the field of cold chain express, S C city needs to fulfill the following characteristics:

1) Cold temperature environment: S C city uses a low temperature environment during cold chain transportation and distribution to ensure the quality and safety of the items.

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2) Timeliness:S company of C city's cold chain transportation and distribution requirements are fast, and we try our best to meet the needs of our customers.

3) Convenience: S C city's cold chain transportation and distribution is as convenient as possible for customers and provides more convenience for customers by offering various ways, such as online ordering and delivery to home.

4) Economic:S company of C city's cold chain transportation and distribution emphasizes economy to ensure economic benefits.

3.3. S C city's Original Distribution Program and Data

3.3.1. Transit Center Distribution Data

Specific coordinates of the outlets.

Coordinates and distribution data are obtained from the field visits of S company of C city, due to the excessive number of outlets owned byS company of C city in the whole C city area, this paper takes Shuangliu area as the research object area, there are a total of 18 outlets post stations and 1 transit distribution center indicated by 0. The outlets post stations are respectively indicated by the natural numbers 1~18, and the relative position of each outlets post station is marked by finding out the actual position on Tencent map. The coordinates of the outlets are obtained by finding the actual location on the Tencent map, marking the relative position of each outlet station, and organizing it to get the coordinates of the stores. The location distribution of the transit and distribution centers and outlet stations is shown in Figure 1, and the location coordinates (X, Y) of each outlet station are shown in the table in km, with the value of the distribution center coordinates being (14, 10.7).

Table 2. Coordinates of Store Station Locations

	1	2	3	4	5	6	7	8	9
X	3	17	6	24	5	16	26	25	3.2
Y	11	12	16	4	8.5	15	7	12	6
	10	11	12	13	14	15	16	17	18
X	12	6.6	27	9	24	22	19.6	15	7.2
Y	6.5	12.6	16.2	7	18	16	11.2	3	2

Source of data: field visits combined with maps

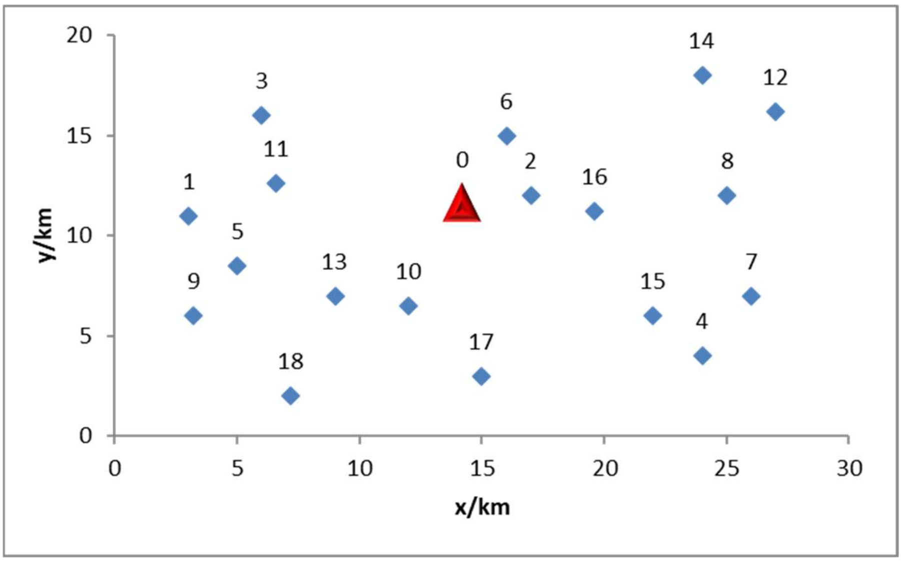

Figure 1. Schematic diagram of the specific coordinates of the store station

Data source: field visits combined with Baidu maps

3.3.2. Initial Test Distribution Data

The transit center arranges 6 distribution vehicles to complete the daily distribution task of cold chain express mail in 18 outlets, and the mileage data, actual loading rate, and actual loading volume of each cold chain distribution vehicle, as well as the arrival time of the vehicle for the initial route before optimization are shown in the table below:

Table 3. Distribution Route, Initial Load/Rate, and Miles Traveled Data Table

Vehicle number	Distribution routes	Load/kg	Loading rate/%	Mileage/km
1	0->2->16->6->0	1537	76.85	19.283
2	0->14->12->8->0	1662	83.1	36.763
3	0->15->4->7->0	1702	85.1	28.253
4	0->10->17->18->0	1373	68.65	27.253
5	0->13->9->5->0	1353	67.65	24.726
6	0->1->3->11->0	1382	69.1	25.672

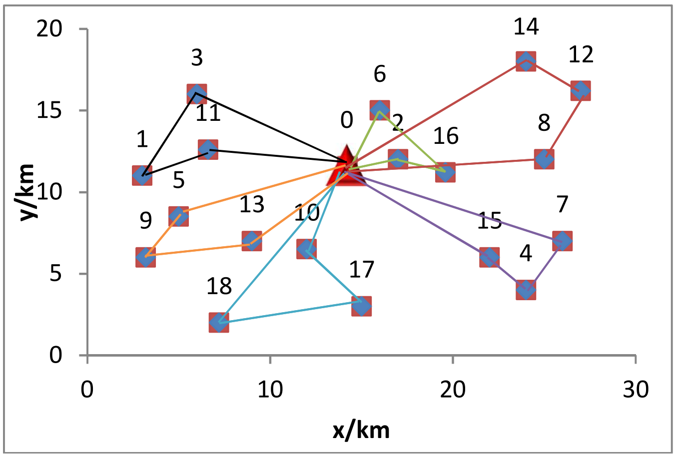

Figure 2. Original Distribution Route Map (schematic only, no specific road conditions indicated)

3.3.3. Reasons for Original Distribution Route Design:

Table 4. Initial Route Vehicle Arrival Times

Customer Number	Arrival time/hour: minutes	Advance + or delay - time/minute
1	5:12	0
2	5:08	0
3	5:26	0
4	5:24	0
5	5:47	-7
6	5:42	0
7	5:48	0
8	5:46	0
9	5:27	0
10	5:09	0
11	5:48	-8
12	5:25	0
13	5:11	0
14	5:09	+4
15	5:10	0
16	5:23	0
17	5:24	-4
18	5:45	0

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Table 5. Table of Vehicles Not Distributed as Planned

Customer Number	Vehicle number	Advance or delay time/minute
5	5	-7
11	6	-8
14	2	+4
17	4	-4

As the development of cold chain express delivery is still in its initial stage, the development time is not too long. Therefore, the initial route has not been planned through the average amount of cold chain express demand of each store, and the drivers of each vehicle still distribute based on their own subjective experience of the distribution route of the ordinary express, so there is a defect of a high rate of empty vehicles, which leads to the waste of enterprise expenditure because of the ineffective utilization of resources.

Of all the stores, four stores, 5, 11, 14 and 17, did not receive the cold chain express shipments according to the planned time points, including at customer 14 where the vehicle delivered the cold chain express shipments to the store post ahead of time, and at 5, 11 and 17 where it exceeded the time required by the store post, i.e., failed to deliver the cold chain express shipments on time and within the time limit.

3.3.4. Initial Distribution Cost Data

Table 6. Initial Distribution Cost Data

Vehicle number	Fixed costs/￥	Fuel consumption cost/￥	Maintenance costs	Cooling costs
1	106	26.9962	1.9283	1.9283
2	106	51.4682	3.6763	3.6763
3	106	39.5542	2.8253	2.8253
4	106	38.1542	2.7253	2.7253
5	106	34.6164	2.4726	2.4726
6	106	35.9408	25.672	25.672

3.4. Analysis of Distribution Problems in S C city

After the field study, it was found thatS company of C city was transported by the distribution personnel with subjective experience in the process of transit distribution, and the distribution path lacked rationality and scientificity, which in turn led to an increase in the transportation time and the distribution task. After investigation and research, the following four main problems exist in the distribution of Q enterprise:

1) Low vehicle loading rate

Transit center to outlets in the distribution process by the staff in the subjective experience of transportation, the lack of science and rationality, which in turn led to an increase in the transport time and distribution tasks. Through the field visit, it was found that the management and arrangement of the distribution vehicles of S company of C city were mainly decided by the distribution administrator based on general experience, while the loading rate of the vehicles was lower than 70%, a situation that led to low transportation efficiency.

2) Delivery delay

The research found that vehicles from S C city's transit and distribution center to outlets did not follow the specified time for daily cold-chain express delivery, and that early delivery brings the cost of waiting time, while delayed delivery increases the cost of risky loss of product spoilage. Unreasonable distribution routes lead to the occurrence of advance or delay.

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4. S C city Company Cold Chain Distribution Problem Modeling

4.1. Reasons for Modeling

The vehicle path optimization problem has always been a difficult problem forS company of C city to solve in delivering express shipments to the outlets in bulk, especially in the transportation of cold chain express shipments, due to the difficult to save nature of the loaded objects, it is extremely important to be able to deliver each express shipment to the destination with the optimal efficiency. However, the complexity of the path optimization problem is mainly reflected in the fact that it requires the comprehensive treatment of multiple parties to make trade-offs, and the previous theoretical methods can not really solve the problem effectively in practice. Therefore, it is necessary to design a model algorithm tailored to the needs of the local conditions, build a relevant logistics mathematical model, and then combine with the actual situation of the S Company to optimize the actual distribution path with scientific algorithms.

4.2. Modeling Assumptions

In order to ensure the rigor of the model construction and to take into account the reality, it is necessary to assume certain restrictive propositions as the premise of the model formulation:

4.2.1. On Cold Chain Vehicles and Routes:

1) There is only one distribution route for each cold chain vehicle, and each store is subject to only one cold chain vehicle providing transportation services for it;

2) The actual load of each vehicle used for cold chain purposes shall not exceed the rated load mentioned above in this document;

3) The speed of the delivery vehicle is maintained at a certain level and the traffic is smooth, without taking into account the delay in delivery due to small probability events caused by force majeure factors.

4.2.2. On temperature:

1) The interior refrigeration of the distribution vehicle is kept constant;

2) The loss rate of cold-chained express shipments will increase with the rise in ambient temperature and the increase in time in transit.

4.2.3. On Stores as Well as Cold Chain Express:

1) The distance between each store and the transit center can be measured by data;

2) The demand for the number of cold chain couriers required by the store is predictable by the number of households around the store, and the demand value can be obtained relatively and with less fluctuation.

4.3. Definition and Description of Model-related Parameter Symbols

4.3.1. Variable Modules

Table 7. Variable Definitions

variant	define
a_{ijm}	$a_{ijm} = \begin{cases} 1, indicates\ that\ the\ vehicle\ is\ in\ use\ and \\ the\ delivery\ vehicle\ m\ is\ traveling\ from\ i\ to\ j \\ 0, \text{No (vehicles not in use)} \end{cases}$
β_{im}	$\beta_{im} = \begin{cases} 1, \text{indicates that the vehicle is in use and} \\ \text{the target customer i is delivered by vehicle m} \\ 0, \text{No (vehicles not in use)} \end{cases}$
γ_m	$\gamma_m = \begin{cases} 1, \text{indicates that the vehicle is in use and vehicle m is in transit} \\ 0, \text{No (vehicles not in use)} \end{cases}$

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4.3.2. Symbol Module

Table 8. Symbol Definitions

notation	define	unit (of measure)
M	Indicates a cold chain distribution vehicle	--
$i$respond in singing$j$	Indicates that S C city has a certain stage store.	--
Y	The respective overall objective function for each model	--
A	Maximum mileage per cold chain vehicle	km
a	Clients$i$ Distance to target customer$j$ Distance	km
Q	Maximum rated capacity per vehicle for cold chain use	kg
q	Customer$i$ Demand for delivery of goods	kg
V	Average vehicle travel speed	Km/h
C	Unit transportation cost per vehicle mile for cold chain	Yuan

4.4. S company of C city Logistics and Distribution Optimization Model Construction

4.4.1. Transformation of Individual Objective Functions

Fixed costs.

Fixed costs specifically refer to the expenses that have been fixed for the vehicle, the size of the number of which has no relation to the distance and time that the vehicle needs to be distributed, such as the depreciation of the vehicle. After the fieldwork visit, the fixed cost of the vehicles used in the cold chain of S company of C city is ￥106/vehicle.

$$\mathrm{minY}_1 = 106 * \sum_{m=1}^{\gamma} \sum_{j=1}^{n} \beta_{0j} \tag{6}$$

Fuel cost.

The cost of fuel consumption specifically refers to the cost of fuel consumed by cold chain vehicles in the process of distribution because of the use of fuel as an energy source, which is positively correlated with the distribution distance of the vehicle, i.e., the further the distance traveled, the higher the cost of fuel consumption used;

$$\mathrm{minY}_2 = \mathrm{C}_1 * \sum_{m=1}^{\gamma} \sum_{i=0}^{n} \sum_{j=0}^{n} a_{ij}\alpha_{ijm} \tag{7}$$

Maintenance cost.

Maintenance cost refers to the vehicle in daily use, parts and components need to be replaced when the failure of the cost spent; in order to model the readability of the construction of the vehicle's cleaning costs and maintenance costs in this paper is temporarily categorized as the maintenance cost of which;

$$\mathrm{minY}_3 = \mathrm{C}_2 * \sum_{m=1}^{\gamma} \sum_{i=0}^{n} \sum_{j=0}^{n} a_{ij}\alpha_{ijm} \tag{8}$$

Refrigeration cost.

Refrigeration cost specifically refers to the distribution of cold chain express, because of the special characteristics of the express, need to maintain the temperature of the express at the standard, that is, the need to use the cold chain vehicle for distribution. In the delivery process, the refrigeration function and temperature monitoring function need to rely on funds to maintain, and then produce refrigeration distribution. The more express shipments, the longer the transportation distance, will make the cost of refrigeration increase;

$$\min Y_4 = C_3 * \sum_{m=1}^{\gamma} \sum_{i=0}^{n} \sum_{j=0}^{n} a_{ij}\alpha_{ijm} \tag{9}$$

Table 9. Definition of Parameter Symbols Used

parameter symbol	Parameter Definition	parameter value	unit (of measure)
C_0	Start-up costs for distribution vehicles	106	Yuan/vehicle
C_1	Unit cost of fuel consumption for miles traveled by distribution vehicles	1.4	Yuan/km
C_2	Unit repair and maintenance costs for miles traveled by distribution vehicles	0.1	Yuan/km
C_3	Unit cost of refrigeration for miles traveled by distribution vehicles	0.1	Yuan/km
V	Average speed of distribution vehicles	50	Km/h
Q	Maximum load of distribution vehicles	2000	Kg

4.4.2. Modeling

Based on each of the multi-objectives listed above and in conjunction with the field survey, the following logistics model was developed:

$$\min Y = \min Y_1 + \min Y_2 + \min Y_3 + \min Y_4 \tag{10}$$

s.t.

$$\sum_{i=0}^{n} \sum_{j=o}^{n} a_{ij}\alpha_{ijm} \le A \ , m \in m \tag{11}$$

$$\sum_{i=1}^{n} q_1\beta_{im} \ \le Q, m \in m \tag{12}$$

$$\sum_{m=1}^{\gamma} \gamma_m \le M, \tag{13}$$

$$\sum_{m=1}^{\gamma} \beta_{ijm} = 1 \, , i \in \mathrm{n} \tag{14}$$

$$\sum_{j=1}^{n} \alpha_{ijm} = \beta_{im} \, , i \in N \tag{15}$$

$$\sum_{i=1}^{n} \alpha ijm = \beta_{jm} \, , j \in N \tag{16}$$

$$\sum_{j=1}^{n} \beta_{0jm} = \sum_{i=1}^{n} \beta_{i0m} = u_m \, , m \in M \tag{17}$$

$$\sum_{j=0}^{n} \alpha_{ijm} = \sum_{j=0}^{n} \alpha_{jim}, i \ne j \, ; i \in N; m \in M \tag{18}$$

$$\alpha_{ijm} + \alpha_{jim} \le 1 \tag{19}$$

$$\alpha_{ijm}\left(1 - \alpha_{ijm}\right) = 0, i \in N; j \in N; m \in M \tag{20}$$

$$\beta_{im}(1 - \beta_{im}) = 0, i \in N; m \in M \tag{21}$$

$$\gamma_m(1 - \gamma_m) = 0, m \in M \tag{22}$$

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The objective function (10) is the optimization objective of the problem, which needs to minimize the total distribution cost or maximize the total distribution benefit. The distribution cost can be the total mileage traveled by the vehicles, the total time, the total fuel consumption, and so on.

In total, the constraints include a limit on the maximum distribution mileage of each vehicle (11), a limit on the rated load of the vehicle (12), the total number of cars used is not greater than the number of vehicles owned by the distribution center (13), each customer can and will be served by only one vehicle (14 through 16), each vehicle used must depart from the distribution center and must eventually return to the distribution center (17), the equilibrium of the number of vehicle entries and exits (18), the inability of a vehicle to return to the previous customer when it reaches the next customer (19), and the range of values for the decision variables (20 through 22).

5. Solving and Analyzing the Cold Chain Path Problem of Logistics and Distribution of S company of C city

5.1. Distribution Dimensions Data and Parameters

5.1.1. Company Distribution Data

1) Matrix of distances between store posts and each other

In this paper, spatial coordinate distances are used to estimate actual distribution distances. Specifically, the Euclidean distance is used to compute the data in calculating the distance between two points.Euclidean distance is abbreviated as Euclidean distance, which refers to a type of distance in Euclidean space where two points are on a straight line. The Euclidean distance is utilized to represent the distance between two points in Euclidean metric space.

Any two points(x_i, y_i) and(x_j, y_j) The distance between them can be expressed as:

$$\mathrm{d_{ij}} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{23}$$

2)The matrix information is shown in

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	0	11.2	3.2	10.2	12.5	10.3	4.2	13.5	11.2	12.2	4.8	8.9	14.2	7.2	12.1	7.8	5.1	8.9	9.4
1	11	0	14.7	7.8	22.3	3.4	17.3	21.3	20.2	4.2	12.2	6.3	22.1	8.6	22.3	17.6	14.5	14.3	8.6
2	3.2	14.7	0	12.1	12.7	11.2	4.2	14.7	7.3	14.5	6.9	14.2	14.3	11.5	11.2	8.6	3.1	8.6	13.9
3	10.2	7.8	12.1	0	19.6	8.9	11.2	22.5	20.2	11.5	12.5	4.1	21.7	9.6	20.6	19.7	15.7	14.4	14.6
4	12.5	22.3	12.7	19.6	0	21.6	13.2	3.6	8.9	21.3	14.7	17.3	14.2	16.2	16.7	4.6	7.6	9.4	18.3
5	10.3	3.4	11.2	8.9	21.6	0	14.2	20.7	21.2	4.3	7.4	6.7	24.6	6.4	20.1	17.8	15.7	12.2	7.6
6	4.2	17.3	4.2	11.2	13.2	14.2	0	13.7	9.9	13.4	8.7	11.7	12.5	11.4	11.3	11.7	6.9	12.7	14.2
7	13.5	21.3	14.7	22.5	3.6	20.7	13.7	0	7.2	21.3	12.7	21.2	8.9	16.7	11.7	6.1	8.6	12.4	18.2
8	11.2	20.2	7.3	20.2	8.9	21.2	9.9	7.2	0	21.7	16.2	16.7	5.2	16.3	7.9	9.1	7.2	17.3	19.2
9	12.2	4.2	14.5	11.5	21.3	4.3	13.4	21.3	21.7	0	7.2	8.3	26.9	8.6	25.8	20.1	21.2	12.1	6.3
10	4.8	12.2	6.9	12.5	14.7	7.4	8.7	12.7	16.2	7.2	0	8.8	21.2	4.2	19.5	13.7	12.7	6.8	7.9
11	8.9	6.3	14.2	4.1	17.3	6.7	11.7	21.2	16.7	8.3	8.8	0	21.2	7.8	17.8	21.2	14.2	14.2	12.1
12	14.2	22.1	14.3	21.7	14.2	24.6	12.5	8.9	5.2	26.9	21.2	21.2	0	21.4	4.3	11.2	11.7	16.7	23.7
13	7.2	8.6	11.5	9.6	16.2	6.4	11.4	16.7	16.3	8.6	4.2	7.8	21.4	0	18.9	12.7	12.1	8.9	7.2
14	12.1	22.3	11.2	20.6	16.7	20.1	11.3	11.7	7.9	25.8	19.5	17.8	4.3	18.9	0	16.2	12.1	16.2	21.2
15	7.8	17.6	8.6	19.7	4.6	17.8	11.7	6.1	9.1	20.1	13.7	21.2	11.2	12.7	16.2	0	7.8	9.4	14.2
16	5.1	14.5	3.1	15.7	7.6	15.7	6.9	8.6	7.2	21.2	12.7	14.2	11.7	12.1	12.1	7.8	0	8.7	14.7
17	8.9	14.3	8.6	14.4	9.4	12.2	12.7	12.4	17.3	12.1	6.8	14.2	16.7	8.9	16.2	9.4	8.7	0	7.6
18	9.4	8.6	13.9	14.6	18.3	14.2	14.2	18.2	19.2	6.3	7.9	12.1	23.7	7.2	21.2	14.2	14.7	7.6	0

Figure 3. Store Post Distance Matrix

3) Data on the need for cold chain express delivery in each store

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The weight of cold chain shipments in stores is calculated based on the average of past demand, and the demand for cold chain shipments is stable due to the number of households in the vicinity of the store.

4) Parameterization and Model Architecture

S C city has 6 cold chain distribution vehicles of the same functional type, with a maximum load capacity of 2000kg and vehicle dimensions of 4.2*1.8*1.85.m^3 The specific parameters are shown in the table:

Table 10. Specific data for each parameter

parameter symbol	Parameter Definition	parameter value	unit (of measure)
C_0	Start-up costs for distribution vehicles	106	Yuan/vehicle
C_1	Unit cost of fuel consumption for miles traveled by distribution vehicles	1.4	Yuan/km
C_2	Unit repair and maintenance costs for miles traveled by distribution vehicles	0.1	Yuan/km
C_3	Unit cost of refrigeration for miles traveled by distribution vehicles	0.1	Yuan/km
V	Average speed of distribution vehicles	50	Km/h
Q	Maximum load of distribution vehicles	2000	Kg

Based on each of the multi-objectives listed above and in conjunction with the field survey, the following logistics model was developed:

$$\mathrm{minY} = \mathrm{minY}_1 + \mathrm{minY}_2 + \mathrm{minY}_3 + \mathrm{minY}_4 \tag{24}$$

s. t.

$$\sum_{i=0}^{n} \sum_{j=o}^{n} a_{ij} \alpha_{ijm} \leq A \ , m \in m \tag{25}$$

$$\sum_{i=1}^{n} q_1 \beta_{im} \ \leq Q, m \in m \tag{26}$$

$$\sum_{m=1}^{\gamma} \gamma_m \leq M, \tag{27}$$

$$\sum_{m=1}^{\gamma} \beta_{ijm} = 1 , i \in \mathrm{n} \tag{28}$$

$$\sum_{j=1}^{n} \alpha_{ijm} = \beta_{im} , i \in N \tag{29}$$

$$\sum_{i=1}^{n} \alpha ijm = \beta_{jm} , j \in N \tag{30}$$

$$\sum_{j=1}^{n} \beta_{0j} \quad = \sum_{i=1}^{n} \beta_{i0m} = u_m , m \in M \tag{31}$$

$$\sum_{j=0}^{n} \alpha_{ijm} = \sum_{j=0}^{n} \alpha_{jim}, i \neq j ; i \in N; m \in M \tag{32}$$

$$\alpha_{ijm} + \alpha_{jim} \leq 1 \tag{33}$$

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$$\alpha_{ijm}(1-\alpha_{ij}\quad)=0, i\in N; j\in N; m\in M \tag{34}$$

$$\beta_{im}(1-\beta_{im})=0, i\in N; m\in M \tag{35}$$

$$\gamma_{m}(1-\gamma_{m})=0, m\in M \tag{36}$$

5.2. Solving and Analyzing the Actual Problem of S company of C city

5.2.1. Optimization of Cold Chain Vehicle Distribution Routes

For different vehicles, the distribution tasks are different. The area in charge is also different, here the calculation is done with vehicle 2 as an example, and the detailed process is as follows: (Note: Since the specifications of each cold chain vehicle are the same, the fixed cost is the same, and the difference is mainly reflected in the different fuel consumption costs caused by the length of the routes, and the forked roads encountered in the routes that vehicle 2 passes through are more typical, and the optimization effect is more significant, therefore, the calculation here is done with vehicle 2 as a good example).

(1) The first step involves comparing the distances between each store-station and the transit center to each other, and then selecting the store-station that is relatively closer according to each step of the route. Take Store 14 as an example, first find out all the routes that can be passed from the transit center to Store 14, and mark the transit center V0 as P, P (V0 =0), and finally mark the remaining points.

(2) Since (V0 ,Va)=8.2km, (V0 ,Vb)=6.7km, modify the labeling of these two points:

T (Va) = min[T (Va), P (V0) + L0a] = min[∞, 0 + 8.2] = 8.2km.

T (Vb) = min[T (Vb), P (V0) + L0b] = min[∞, 6.7] = 6.7km.

By comparing the labels of the individual T's, it can be concluded that T (Vb) is the smallest, i.e., P (Vb) = 6.7km, which is then recorded as:

Path (V0 ,Vb)=6.7km.

(3) Label P on the just obtained Vb , since there is and only one path from Vb to V14 , the shortest path from V0 to V14 is: V0 ,Vb ,V14.

(4) Then, based on the load, after arriving at store 14, label store 14 with P, P (Vb = 5.8), and label the remaining point T,T (vi = ∞).

(5) There are two roads from V14 which are (V14 ,Vc)=2km,(V14 ,Vd)=5.6km, update the labeling of the two points here based on the above data:

T (Vc) = min[T (Vc), P (V14) + L14 c] = min[2, 5.8 + 2] = 2km.

T (Vd) = min[T (Vd), P (V14) + L14 d] = min[5.6, 5.8 + 5.6] = 5.6km.

Comparing the labels of all the T's, it is concluded that T (Vc) has the smallest distance, so P (Vc) = 2km and record the path (V14 ,Vc) = 2km.

(6) Vc is the point where we just got the P label, from Vc there is and only one traveling path to consider (Vc ,V12), so (Vc ,V12) = 3.3km. and record the path (Vc ,V12) = 3.3km.

(7) V12 is the point where we have just obtained the P-label, and since there is and only one straight line travel path from V12 to V8 , (V12 ,V8) = 5.2km.

In summary, the customer delivery path for vehicle 2 is: V0 ,Vb ,V14 ,Vc ,V12 ,V8 ,V0.

The above is the distribution path optimization for vehicle 2, and the path optimization steps for the rest of the vehicles are the same as above. After verification, the actual load capacity and mileage of the five vehicles are calculated to be within the rated range.

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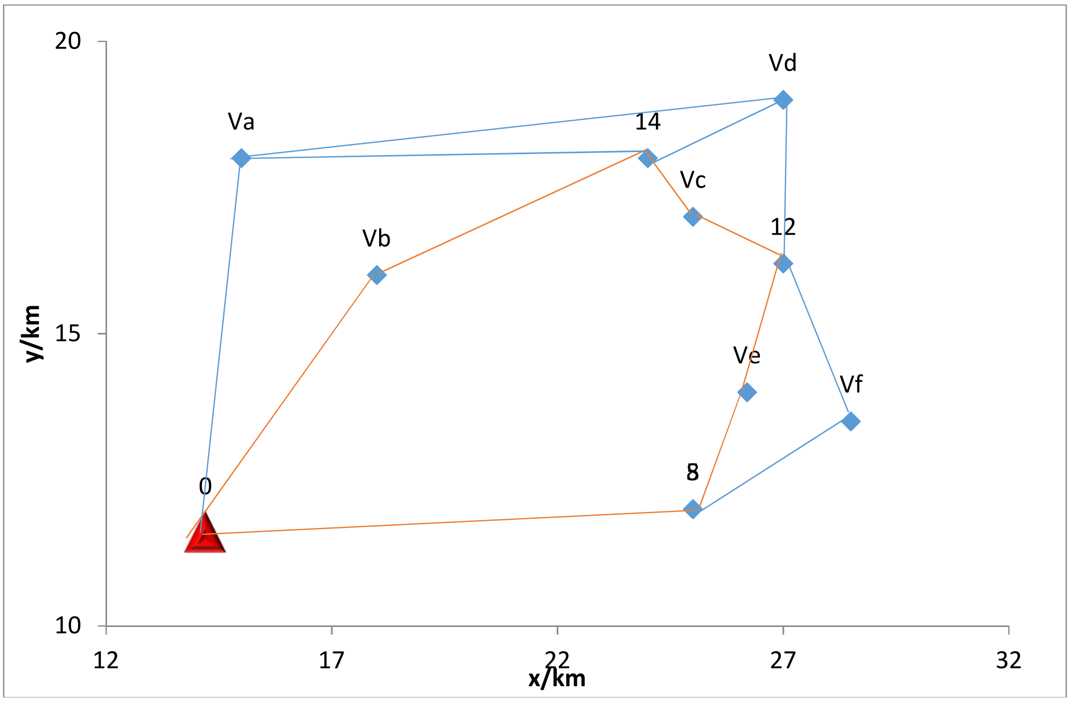

Figure 4. Final Optimization Roadmap with Vehicle 2 as an Example

Based on the data obtained from the field research and interview of C city S Company, the distribution routes of each vehicle are finally optimized to solve the constructed model, and the final output of the optimized distribution roadmap is shown in Fig:

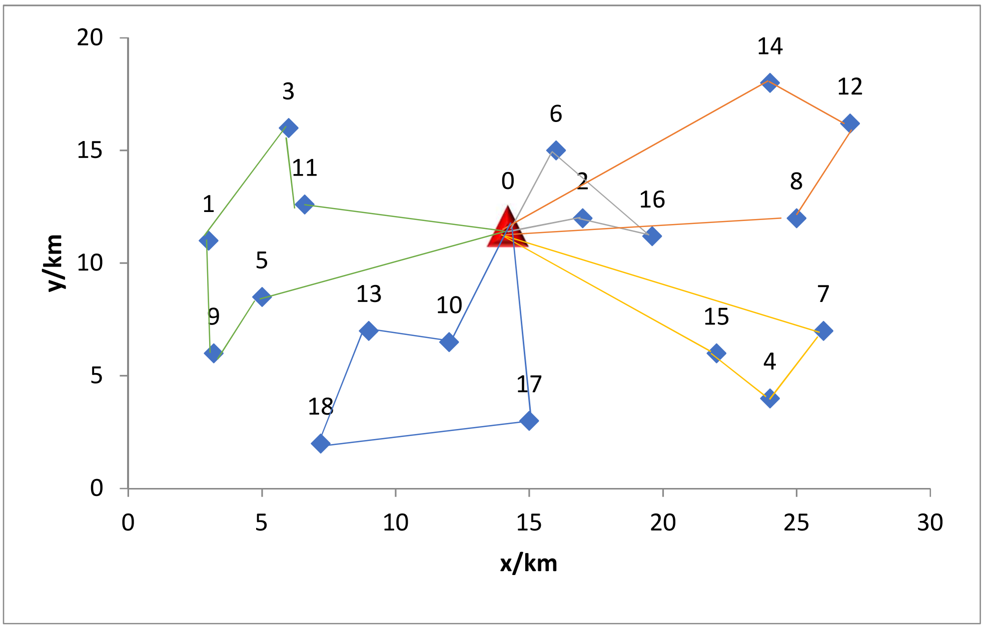

Figure 5. Final Optimized Distribution Map

5.2.2. Specific Distribution Route Chart and Precise Link Arrival Times

(1) Distribution routes and times:

C city's Transshipment and Distribution Center used five vehicles to complete deliveries to 18 store locations. After arriving at each of these stations, the vehicles need to spend a certain amount of time handling and unloading before driving to the next station. The specific statistics of each route and each dimension are shown in the table:

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Table 11. Optimized Distribution Routes and Arrival Times

Vehicle number	Delivery route order and arrival time							
1	order of delivery	hub (network equipment)	Store 2	Store 16	Store 6			Back to the transit center
	Arrival time	5:00	5:07	5:25	5:41			5:55
2	order of transit	hub (network equipment)	Stores 8	Store 12	Store 14			Back to the transit center
	Arrival time	5:00	5:09	5:22	5:29			5:42
3	order of delivery	hub (network equipment)	Store 15	Store 4	Store 7			Back to the transit center
	Arrival time	5:00	5:18	5:23	5:38			5:51
4	order of delivery	hub (network equipment)	Stores 10	Store 13	Stores 18	Store 17		Back to the transit center
	Arrival time	5:00	5:13	5:24	5:45	5:59		6:15
5	order of delivery	hub (network equipment)	Stores 11	Store 3	Store 1	Store 9	Stores 5	Back to the transit center
	Arrival time	5:00	5:13	5:29	5:51	6:07	6:18	6:31

Data source: optimized survey results.

(2) Advance or delayed status

After the optimization, early delays were reduced at all stages, and the evaluation of the transit center by each store was significantly higher.

(3) Optimized distribution data

1) Loading rate = actual vehicle load / vehicle specified load, vehicle 1 load = 1669/2000 * 100% = 83.45%, the same reasoning to find the rest of the vehicle loading rate were 83.7%, 85.95%, 88.75%, 98.15%, 95.65%

2) Fixed costs:

$$\min Y_1 = 106 * \sum_{m=1}^{u} \sum_{j=1}^{n} x_{0j} \quad =106*5=530 \tag{37}$$

3) Cost of fuel consumption:

$$\min Y_2 = C_1 * \sum_{m=1}^{u} \sum_{i=0}^{n} \sum_{j=0}^{n} a_{ij} \alpha_{ijm} \tag{38}$$

Take vehicle #2 for example: cost of gas = ￥33.4*1.4 = ￥46.76.

4) Maintenance and repair costs:

$$\min Y_3 = C_2 * \text{mileage} \tag{39}$$

Take vehicle #2 for example: maintenance cost = ￥33.4*0.1=￥3.34.

5) Mileage:

Vehicle 2 mileage = 6.7 + 5.8 + 2 + 3.3 + 11.2 + 5.2 = 33.4km.

6) Refrigeration costs

$$\mathrm{minY}_4 = \mathrm{C}_3 * \mathrm{mileage} \tag{40}$$

Using vehicle #2 as an example: cost of cooling = ￥33.4*0.1=￥3.34.

The total cost is equal to the sum of the above costs of ￥761.32.

Table 12. Data table of optimized individual costs

Vehicle number	Fixed costs/￥	Fuel consumption cost/￥	Maintenance costs	Cooling costs	Total delivery cost/￥
1	106	22.7962	1.6283	1.6283	147.84
2	106	46.8482	3.3463	3.3463	183.52
3	106	39.5542	2.8253	2.8253	156.16
4	106	47.9542	3.4253	3.4253	171.2
5	106	45.2564	3.2326	3.2326	168.16

Table 13. Summary of Optimized Data

Distribution category	sum of money
Vehicle utilization/unit	5
Average loading rate/%	90.44
Mileage/km	144.578
Repair and maintenance cost/￥	14.4578
Total refrigeration cost/￥	14.4578
Total fuel cost/￥	202.4
Fixed costs/￥	530
Total cost/￥	761.3156

5.2.3. Comparison of Optimized Sequential Data

After optimization, the total cost is reduced to 761.3156 by using 5 cold chain distribution vehicles, before and after comparison as shown in the table below:

Table 14. Comparison of various data after optimization

Distribution data	starting value	post-optimization	magnitude of change
Vehicle utilization/unit	6	5	Reduction by 1
Average loading rate/%	75.075%	90.44%	15.355% increase
Mileage/km	161.95	144.578	Reduced by 17km
Repair and maintenance cost/￥	39.3	14.4578	Decrease of ￥24.84
Total refrigeration cost/￥	39.3	14.4578	Decrease of ￥24.84
Total fuel cost/￥	226.73	202.4	Decrease of ￥24.33
Fixed costs/￥	636	530	Reduction of ￥106
Total cost/￥	941.33	761.3156	180.0144

1) By comparing the data, it can be learned that the total distribution cost of the optimized solution is reduced to ￥761.32, which is a reduction of ￥180. At the same time, other parameters have also been improved to a certain extent after optimization. Compared with the

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distribution plan before optimization, the optimized plan is obviously more scientific, so as to achieve the effect of cost reduction and efficiency. For the enterprise to save 180 yuan per day, saving 5,400 yuan per month.

2) The use of vehicles has also been reduced from six to five, forS company of C city transit center operations to reduce a lot of pressure, saving vehicle operation at the same time, the previously idle vehicles can also be used for rental or to provide value-added services, creating value again.

3) Shorten the time of cold chain goods in transit, save costs at the same time, faster delivery into the fixed cold storage can reduce the loss of goods.

6. Conclusion

In the actual distribution of S company of C city, there are still many problems to be solved. For example: the vehicle loading rate is not high, the distribution time is not accurate, and the distribution mileage and time are far from the plan. After researching this paper, the main conclusions are as follows:

(1) Starting from the actual problem of S company of C city, a multi-objective model is established, and multiple dimensions are considered to optimize the cost under the actual premise: balancing the relationship between the operation cost of the transit center and the timely delivery of stores, and the relationship between the driving safety coefficient and the loss of cold-chained products, respectively, and considering the limitations on the actual load capacity of the vehicle, the limitations on the maximum mileage of the vehicle, and the customer's delivery time requirements into the model. The model is designed to incorporate the limitation of the actual load capacity of vehicles, the limitation of the maximum mileage of vehicles and the requirements of customers' delivery time into the model. This will improve the overall level of efficiency.

(2) Combining the company's annual report and entity inspection, relevant premises and constraints are carried out before model construction to make the algorithm more practical value. Using dijkstra's algorithm for optimization and comparing the initial data with the optimized data, it can be concluded that the optimization helps to complete the distribution task faster and shorten the time of goods in transit. The algorithm is used to carry out the solution of the path problem, and finally find the optimized distribution path for 5 vehicles, and the data comparison learns that, compared with the initial data, the total cost is reduced by 101 yuan/day, 17km, and the loading rate is increased by nearly 15%, which greatly improves the utilization of resources.

(3) From the viewpoint of the main body of S company of C city, the optimization method for the company has brought greater economic benefits, cost savings in all dimensions of data have a certain optimization effect, the optimization of the allocation of resources for the entire enterprise, and reduce the loss of express items to ensure that the quality of delivery to the hands of the user to improve user satisfaction, and to enhance the company's core competitiveness and brand influence.

From the aspect of the main content of this paper, this paper constructs a cold chain express delivery path optimization model fromS company of C city's transit center to store post, which is studied under ideal conditions. However, in practical application, external factors such as natural disasters, road conditions and other emergencies excluded in the assumption premise of this paper will have an impact on the distribution process, which may lead to distribution delays, rotting and loss of goods, and other distribution damage phenomena. In addition, the data studied in this paper is based on same-day distribution, which requires the establishment of a dynamic model to adjust the path in time to comply with real-time distribution. These

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improvements can improve the practicality and applicability of the model and provide a more effective solution for cold chain express logistics distribution.

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