Optimization of delivery Route for E-commerce freshmen based on two-level Logistics system

Jingming Wang[1], Hong Liu [2], Luyao Zhong[3]

[1]School of Transportation, Shanghai Maritime University, Shanghai, China

[2]School of Transportation, Shanghai Maritime University, Shanghai, China

[3]School of Foreign languages, Shanghai Maritime University, Shanghai, China

Abstract

In recent years, with the development of urban planning, the layout of the city has been constantly changing. For e-commerce, the layout of the consumer group has also changed, resulting in high cost in the traditional point-to-point single-line distribution mode, which hinders e-commerce are further profiting in the fresh market.Therefore, this paper studies the heterogeneous vehicle routing problem of the two-level logistics system of e-commerce fresh cold chain distribution, combined with the distribution mileage and time, fresh cargo damage, vehicle maintenance cost, driver salary, etc., with the lowest fresh loss. The minimum sum of the cost of the vehicle and the cost of the vehicle is the target. The fresh loss distribution model of the heterogeneous vehicle is established, the traditional cw algorithm is improved, the existing distribution route is optimized, and the model is confirmed by actual cases. Effectiveness provides a certain practical guiding significance for e-commerce companies.

Keywords

Two-level logistics system; Heterogeneous vehicle; VRP; Fresh delivery.

1. Introduction

In recent years, as a rapidly developing and increasingly mature form of e-commerce, fresh e-commerce has been favored by giants. Based on the characteristics of high refrigeration requirements, short shelf life and easy loss of cold products, cold chain storage and logistics are the necessary choice for fresh e-commerce. As China's third-party cold-chain logistics enterprises are more difficult to complete the fresh-distribution business with scattered locations and unstable delivery time, some of the powerful fresh-keeping e-commerce companies have adopted the self-built cold chain model, which is in the whole process of procurement, storage and distribution to improve customer satisfaction, but the cost is always high, one of the more important reasons is that the participants in the two-level logistics system do not achieve good cooperation and sharing. There are many literatures at home and abroad that have studied the two-level system from many fields of the cold chain. The concept of two-level transport distribution was originally proposed by Li-Lian Gao and E. Powell Robinsion. Jr. Gao and Jr proposed a general model and a solution program based on double branch and bound, which was used to find the multi- Optimal solution of of single-stage, multistage and multi-activity capacity-free facilities [1]; Before 2000, the research on the location of two-level facilities was mainly studied on the problem of vehicle routing, Until 2010, Perboli etal proposed related formulas based on TSP and CVRP, inequalities and transportation system diagrams, and performed calculations on 50 customers. The results showed that the best results are improved by 4% to 15% [5];In 2014, for the first time, two-stage cold chain logistics was proposed. Govindan et al. further did some Research on sustainable development about the location of the logistics distribution center, the environmental impact and the sustainability of the supply chain while considering the optimization of the distribution routes of the echelons for the two-stage distribution of perishable food. He proposed a new algorithm MHPV combining multi-objective particle swarm optimization and adaptive multi-objective domain search. The results showed that the new algorithm was not only superior to traditional algorithms such as genetic algorithm, but also for decision makers to consider the degree of crowding between particles. The result was better than the results obtained using the grid method [12]Two years later, Li proposed a short-term strategy different from Govindan's long-term 2E-VRP strategy namely the line transmission system (2E-TVRP) that did not involve location decision, and confirmed by examples that the strategy solved many practical situations Faster and more effective, For example, from the perspective of environmental issues, Li aimed to reduce the amount of carbon dioxide emitted per kilometer by adjusting the position of the intermediate warehouse and developing a load semi-trailer to eliminate the no-load operation of the tractor. [14].

Although the previous studies on the two-level logistics system have been comprehensive, there are still some research shortcomings:1 At present, the research is mainly on the distribution of refrigerated trucks in two-level logistics. In the previous research, Wang etal mainly focused on specialized refrigerated trucks and general fresh-keeping distribution, but due to the particularity of e-commerce, Most vehicles of the system are non-refrigerated vehicles, and the research on multi-vehicle coordinated distribution mode in e-commerce fresh logistics is still insufficient;2 E-commerce fresh logistics mostly adopts a single transportation mode as shown in Figure. 1 point-to-point, that is the warehouse distributes each node separately, and each node is separately delivered to each consumer group. This way undoubtedly increases the total cost of distribution. Combining the above problems with the reality of e-commerce logistics, this paper introduces a multi-cost heterogeneous vehicle distribution model based on the traditional vehicle routing problem, and changes the traditional point-point distribution mode, and strengthens the cooperation of each level system to reduce the total cost, as shown in Figure 2； At the same time, considering the complexity of e-commerce logistics products, the use of special refrigerated trucks for the distribution of fresh products is too expensive. This paper proposes a solution for the cooperation between warehouses and nodes using common trucks and electric vehicles with cold storage facilities.

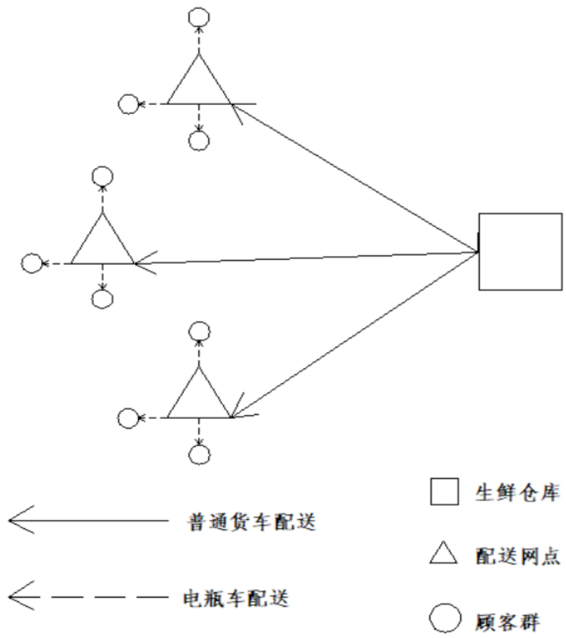

Fig. 1 The traditional point-point distribution mode

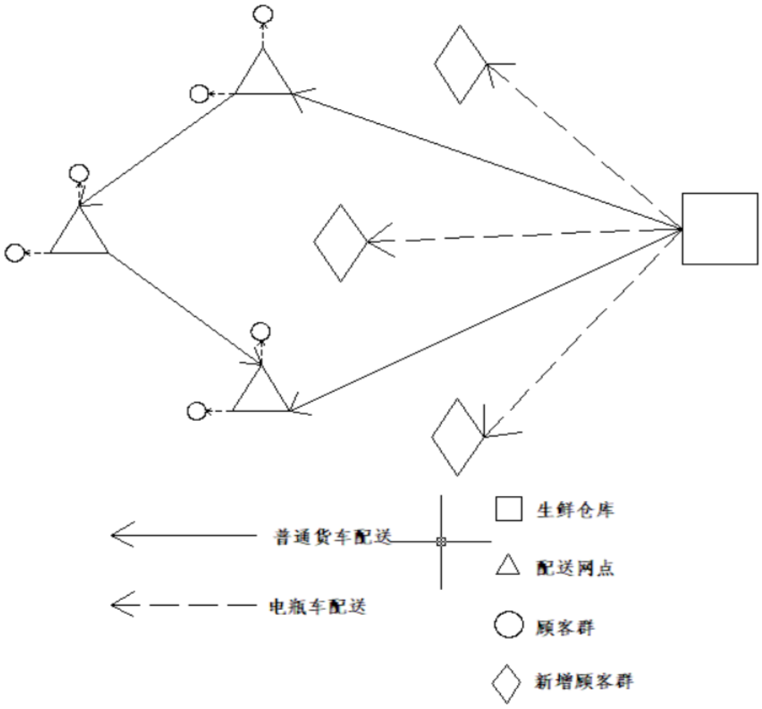

Fig.2 Cooperative distribution mode

2. Model description

Different from the traditional cold chain logistics of fresh products, the e-commerce's fresh food consumption group is mainly family. Although the total demand is large, the demand for each independent consumer is not large, so it increases the cost greatly by adopting specialized refrigerated trucks to delivery goods , the use of ordinary vehicles with freezer and cold storage cabinets is more economical and energy-saving. Since the location of early warehouses and nodes is based on the early urban layout and consumer groups, with the advancement of urban planning and the expansion of consumer groups, The traditional single distribution mode that warehouse directly delivers goods to each distribution node, and the distribution node delivers goods to the consumer groups in the respective service areas of each node increases the unnecessary cost in the distribution greatly. Therefore, according to the actual situation, this paper introduces a heterogeneous vehicle cost model combining fixed cost, cooling cost, transportation cost, cargo damage cost and penalty cost under the conditions of vehicle load and vehicle driving ability.;

2.1 Model assumptions

Due to the reality that the variety of types of fresh products, the uncertainty of daily demand, and the customer groups sent are mostly individual , the following restrictions are required:

The freezer has not been opened before the fresh food is shipped to the customer base;

The vehicles between the echelons return to the starting point after the delivery of the fresh;

In the distribution area of each distribution network, according to the customer's demand, it is divided into several small areas, and the centroid of each small area is taken as the customer group coordinates;

The fresh food delivered by the dispatched outlets is the same temperature requirement;

The daily demand of each distribution node and customer group shall not exceed the maximum load capacity of the delivered vehicle;

(6)The coordinates of fresh warehouse, distribution nodes, customer groups, and distances between points are known;

(7)Each distribution node is only served by one truck, and each consumer group is only served by one electrical vehicle, and the number of vehicles is sufficient and driving at a constant speed;

(8)Fixed expenses are known such as driver's salary, dispatch of staff, maintenance costs etc .

2.2 Symbol definition

I {i/i=1,2,3,…m} is the collection of distribution nodes in the two-echelon logistics system, m is the total number of distribution nodes;

J {j/j=1,2,3…n}is the collection of customer groups in a two-echelon logistics system, n is the total number of customer groups;

G{g/g=1,2,3…q is}a collection of vehicles in a two-echelon logistics system， $g \in i \cup j \cup k$ ， q is the total number of vehicles， {1,2,3…q_0}is trucks， {q_0,q_0+1,q_0+2…q}is electric cars；

K{k/k=m+1} indicates the warehouse in a two-elchelon logistics system；

$d^g{}_{i,j}$ indicates the distance that the vehicle g travel from fresh warehouse to the distribution node or the distribution node to the customer group or the fresh warehouse i to the customer group j. $i, j \in I \cup K \cup J$ ；

D_g indicates the maximum travel distance of the vehicle g；

$C_{\max}$ indicates the maximum load capacity of the delivery truck;

$c_{\max}$ indicates the maximum load capacity of the electric tricycle;

$L^g_{\mathrm{m+1,i}}$ indicates the quantity of goods that are delivered from the fresh warehouse to the distribution node i using the truck g, that is the demand of the node i;

$l^g_{i,j}$ indicates the quantity of goods delivered from the node or warehouse i to the customer group j using an electric tricycle, that is, the demand of the customer group j;

R indicates the number of daily truck shipments;

r indicates the number of daily electric tricycle deliveries;

U_i indicates the order that the distribution node or customer group is served by the delivery vehicle, $i \in k \cup I \cup J$ 。

2.3 Cost Analysis

The objective function of the heterogeneous vehicles constructed in this paper is mainly combined with the fixed cost of trucks and electric tricycles, the transportation cost related to transportation distance and load capacity, the cooling cost of keeping fresh freshness during transportation, and the damage costs during the distribution and unloading process of dispatching personnel.

2.3.1 Fixed cost

Different from the distribution target of general enterprises, the e-commerce fresh distribution target is mainly for families. The distribution of electric tricycles is fast and economical, so the common cost of trucks and electric tricycles should be considered when considering fixed costs. The cost is mainly composed of several factors.: One is the salary of the employee, including the dispatched staff of the warehouse driver and the distribution network, the second is the maintenance cost of wear and tear of the truck , and the third is the battery cost of replacing the battery of the electric tricycle battery. F indicates fixed costs:

$$
\begin{aligned}
F = & \sum_{g=1}^{q} f_g s_g + \\
& \sum_{g=1}^{q_0} \sum_{i=m+1} \sum_{j \in I} (r_{ijg} * L^g{}_{\mathrm{m+1}\,j}) / (C_{\max} * R) * \mathrm{f}_s + \\
& \sum_{g=q_0+1}^{q} \sum_{j \in J} (\delta_{m+1\,jg} * l^g{}_{\mathrm{m+1},\,j}) / (c_{\max} * r) * \mathrm{f}_v + \\
& \sum_{g=q_{0+1}}^{q} \sum_{i \in I} \sum_{i \in J} (\chi_{ijg} * l_{i,j}) / (c_{\max} * r) * \mathrm{f}_v
\end{aligned}
$$

In the formula，g indicates the number of vehicles participating in the distribution， f_g indicates that each driver of the vehicle delivers a fresh salary， s_g is decision variable， s_g if 1 vehicle is used, if it is 0, it is not used.; $L_{m+1,j}$ is the freight volume of the truck from the fresh warehouse to the distribution node, $r_{i,j,g}$ is decision variable，If it is 1, it means that the truck g delivers the goods from the fresh warehouse to the node j. If it is 0, it means that the goods are not delivered. $C_{\max}$ is the maximum load of the truck， R is the number of times a truck delivers daily to a node f_s is the daily maintenance fee of the truck; $l_{m+1,j}$ is the freight volume deliverede from fresh warehouse to customer group of electric tricycles; $c_{\max}$ is the maximum load capacity of an electric tricycle,rIndicates the number of daily delivery of electric tricycles. f_v is the cost of replacing a battery for an electric tricycle . $\delta_{m+1,j,g}$ If it is 1, it means that the electric vehicle g delivers the goods directly from the fresh warehouse to the customer group. If it is 0, it is not. $\chi_{m+1,j,g}$ If it is 1, it means that the electric tricycle g delivers the goods from the distribution network to the customer group. If it is 0, it is not.

2.3.2 Cooling cost

Most of the e-commerce freshgoods are distributed using refrigeration equipment such as freezer boxes. The cost of refrigeration is mainly derived from the introduction of heat load. There are two main sources of heat load.First, due to solar radiation, the vehicle generates heat load into the freezer.The second is the exposure of the freezer during the unloading, and the solar radiation freezer produces a thermal load.Therefore, this paper analyzes the cooling cost from two periods of transportation including loading and unloading.

$$G=\sum_{g=1}^{q_0} p_1\alpha S_1\Delta T_1(t_{he}^{g}-t^{g}{}_{h0})R+\sum_{g=q_0+1}^{q} p_2\beta S_2\Delta T_2(t^{g}{}_{de}-t^{g}{}_{d0})r+\sum_{i=1}^{m}\sum_{g=1}^{q_0} p_1\partial(av_g+b)\Delta T_3 t_{gi} y_i^g r$$

In the formula， p_1 indicates refrigeration cost of the unit heat load of the truck， α is the thermal conductivity of the truck, S_1 is the area of the truck compartment that is exposed to radiation， ΔT_1 is temperature difference between the inside and outside of the freezer in the carriage during the transportation of the truck, t_{h0} is the vehicle to load fresh time from the fresh warehouse, t_{he} is the truck to transport the fresh food back to the fresh warehouse, p_2 is the cooling cost per unit heat load of an electric tricycle compartment, β is thermal conductivity of electric tricycle， S_2 is the radiation area of electric tricycle compartment, ΔT_2 is the temperature difference between the inside and outside of the freezer in the electric tricycle compartment during transportation, $t^{g}{}_{d0}$ is the time that an electric tricycle departs from a fresh warehouse or distribution node. $t^{g}{}_{de}$ the time that electric tricycle delivers the goods back to the fresh warehouse or distribution node, ∂ is the frequency the freezer is handled during loading and unloading, v_g is the volume of all freezers on vehicle g a , b is constants， ΔT_3 is the temperature difference between the inside and outside of the freezer at the time of unloading, t_{gi} is the unloading time of the vehicle g at the distribution node i,， y_i^g is decision variables，If it is 1, it means that the truck g is unloading at the node i. If it is 0, it is not.

2.3.3 Transportation cost

The transportation cost of e-commerce fresh-keeping vehicles is mainly reflected in the fuel consumption of truck vehicles and the power consumption of electric vehicles. The fuel consumption and power consumption are related to the distance of transportation, load capacity and speed.Because this paper assumes that the speed is uniform, there is no need to consider the effect of speed changes on fuel consumption and power consumption, just consider the relationship between distance and load.

$$H=\sum_{g=1}^{q_0}\sum_{i,j\in K\cup I}(\theta_0+\frac{\theta^*-\theta_0}{C_{\max}}C_{i,j})d_{i,j}x_{ijg}R+$$
$$\sum_{g=q_{0+1}}^{q}\sum_{i,j,k\in K\cup I\cup J}(\omega_0+\frac{\omega^*-\omega_0}{c_{\max}}c_{i,j})d_{i,j}z_{ijg}r$$

In the formula， θ_0 indicates the fuel consumption of the truck when it reaches the maximum allowable driving distance when it is running at no load. θ^* indicates the fuel consumption of the vehicle when it reaches the maximum allowable driving distance at full load, $C_{i,j}$ indicates the load of the truck in the arc {i,j}, $c_{i,j}$ indicates the load of the electric tricycle in the arc {i, j},， $d_{i,j}$ indicates the distance between arcs {i, j}, x_{ijg} is the decision variable, if it is 1, it means that the truck g passes the arc {i, j}, if it is 0, it means that it has not passed. ω_0 indicates the power consumption of the electric tricycle when it reaches the maximum allowable driving distance during no-load operation. ω^* indicates consumption of the electric tricycle when it reaches the maximum allowable driving distance when it is fully loaded. z_{ijg} is the decision variable, if it is 1, it means that the electric tricycle passes the arc {i, j}, if it is 0, it means that the electric vehicle does not pass the arc {i, j}.

2.3.4 Cost of goods damage

With the development of the times, the refrigeration capacity of high-performance refrigeration equipment is getting stronger and stronger, and the professionalization of the staff in all aspects of the supply chain is getting higher and higher. The situation of fresh goods damage due to refrigeration and operation is reduced greatly .The internal structure of most fresh products is guaranteed to be relatively stable and shows smaller deterioration in a certain period of time under the current refrigeration conditions and operation, except for a small part of the internal structure that responds quickly and has high temperature and timeliness requirements of perishable and deteriorating fresh products. Therefore, the loss of freshness can be considered as the relationship between transportation time and its ontological spoilage characteristics, and the fresh loss is reduced to a linear function of time.

$$D=e\sum_{i\in I\cup K}\sum_{j\in J}\sum_{g\in G}\lambda Y_{ijg}T_{i,j}$$

e is fresh daily unit price, λ is the rate of corruption of the body during fresh transportation and unloading, $T_{i,j}$ is time for fresh food to be delivered from the warehouse to the customer group, Y_{ijg} is the decision variable, if it is 1, it means that the vehicle g passes the arc {i, j}, if it is 0, it is not.

2.3.5Penalty cost

At present, no matter how much compared to the specialized cold chain logistics enterprises or the e-commerce logistics itself, the amount of fresh food distribution of e-commerce logistics is not too large .The use of high-performance freezer and the efficient loading and unloading and distribution of unloaders and delivery personnel have reduced the cost of damage and the penalty cost beyond the time window limit is negligible, so this article does not impose the study on penalty cost.

3. Model construction

Based on the above analysis of several costs and influencing factors, this section will construct a fresh distribution method and optimization model for e-commerce logistics. Through the analysis of decision-making objectives, this section will minimize the total transportation cost of trucks and electric tricycles as the goal of the model.

$$Z_{\min} = \xi_1 F + \xi_2 G + \xi_3 H + \xi_4 D,$$

$$= \xi_1[\sum_{g=1}^{q} f_g s_g + \sum_{g=1}^{q_0} \sum_{i=m+1} \sum_{j\in I} (r_{ijg} * L^g{}_{m+1j}) /(C_{\max} * R) * f_s +$$ S.T

$$\sum_{g=q_0+1}^{q} \sum_{j\in J} (\delta_{m+1jg} * l^g{}_{m+1,j}) /(c_{\max} * r) * f_v + \sum_{g=q_{0+1}}^{q} \sum_{i\in I} \sum_{i\in J} (\chi_{ijg} * l_{i,j}) /(c_{\max} * r) * f_v] +$$

$$\xi_2[\sum_{g=1}^{q_0} p_1 \alpha S_1 \Delta T_1 (t^g_{he} - t^g{}_{h0}) R + \sum_{g=q_0+1}^{q} p_2 \beta S_2 \Delta T_2 (t^g{}_{de} - t^g{}_{d0}) r +$$

$$\sum_{i=1}^{m} \sum_{g=1}^{q_0} p_1 \partial (a v_g + b) \Delta T_3 t_{gi} y_i^g r)] +$$

$$\xi_3[\sum_{g=1}^{q_0} \sum_{i,j\in K\cup I} (\theta_0 + \frac{\theta^* - \theta_0}{C_{\max}} C_{i,j}) d_{i,j} x_{ijg} R + \sum_{g=q_{0+1}}^{q} \sum_{i,j,k\in K\cup I\cup J} (\omega_0 + \frac{\omega^* - \omega_0}{c_{\max}} c_{i,j}) d_{i,j} z_{ijg} r] +$$

$$\xi_4[e \sum_{i\in I\cup K} \sum_{j\in J} \sum_{g\in G} \lambda Y_{ijg} T_{i,j}]$$

among them, $\xi_1 + \xi_2 + \xi_3 + \xi_4 = 1$

$$\sum_{g=1}^{q_0} \sum_{i=1}^{m} r_{m+1ig} = q_0 \quad (1)$$

$$\sum_{g=q_{0-1}}^{q} \sum_{j=1}^{n} \delta_{m+1jg} + \sum_{g=q_{0-1}}^{q} \sum_{i=1}^{m} \sum_{j=1}^{n} \chi_{ijg} = q - q_0 \quad (2)$$

$$\sum_{g=1}^{q_0} x^{U_i}{}_{m+1jg} = 1$$

$$\sum_{i=1}^{m+1} \sum_{g=q_{0+1}}^{q} z^{U_j}{}_{ijg} = 1 \quad (3)$$

$$\sum_{g=1}^{q_0} \sum_{i=1}^{m} L_{m+1ig} \le q_0 C_{\max} \quad (4)$$

$$\sum_{g=q_{0+1}}^{q} \sum_{i=1}^{m} \sum_{j=1}^{n} l_{ijg} \le (q - q_0) c_{\max} \quad (5)$$

$$\sum_{i=1}^{m+1} \sum_{j=1}^{n} d_{ij} x_{ijg} \le D_g \quad (6)$$

$$\sum_{i=1}^{m} r_{m+1ig} \le C_{\max} \quad (7)$$

$$\sum_{j=1}^{n} \delta_{m+1jg} l_{m+1j} \le c_{\max} \quad (8)$$

$$\sum_{j=1}^{n} \chi_{ijg} l_{ij} \le c_{\max} \quad (9)$$

$$U_i - U_j + (m+n+1)x_{ijg} \leq m+n \quad (10)$$

$$r_{m+1ig}, \delta_{m+1jg}, \chi_{ijg}, x_{ijg}, z_{ijg} \in \{0,1\}, \quad i,j \in K \cup I \cup J \quad (11)$$

Formula (1) indicates that q_0 trucks deliver fresh from the fresh warehouse to the distribution node; Formula (2) indicates that $q-q_0$ Electric tricycles deliver fresh from fresh warehouses or distribution nodes to customers; Formula (3) indicates that each distribution network has one and only one truck service, and each customer group has and is only served by one electric tricycle; Formula (4) indicates that the total demand of the distribution nodes is less than the maximum load capacity of all trucks; Formula (5) indicates that the total demand of the customer base is less than the maximum load capacity of all electric tricycles Formula (6) indicates that the mileage of the vehicle g is less than its maximum driving distance; Formula (7) indicates that the demand for all distribution nodes served by the truck g is less than the maximum load capacity of the truck g itself; Formula (8) indicates that the demand for all customer groups who are serviced by the electric tricycle of fresh warehouse is less than the maximum load capacity of the electric tricycle g itself; Formula (9) indicates that the demand for all customer groups who are serviced by the electric tricycle of distribution node is less than the maximum load capacity of the electric tricycle g ; Formula (10) indicates that the limit of the occurrence of sub-loops; Formula (11) is Constraint variables.

4. Model solving

4.1 Saving Algorithm

4.1.1 Algorithm concept

The C-W saving algorithm belongs to a classic VRP solving algorithm. The algorithm was first proposed by Clark and Wright in 1964, so the algorithm was later called the C-W saving algorithm.

4.1.2 Operation steps of the C-W saving algorithm

(1) For example, firstly treat each of a total of n customers who need goods as a node, secondly select one of the nodes as the base point and set it to 1.

(2) The remaining n-1 nodes and the base point are respectively connected into n-1 line segments, the mileage of the line segment after the node and the base point are connected with the symbol $C_{1j}\,(j = 2,3,4\ldots n)$.

(3) Connect node i to the node j$(i \neq j \neq 1)$,derivation of the formula for calculating the saved value of the generated distance:

$$S(i,j) = C_{1i} + C_{1j} - C_{i,j}$$

Calculate the value of the savings by connecting all the resulting nodes to each other, and sort all the calculated s(i,j), the sorting rules are sorted according to the saving value from large to small, and the node with the largest saving value calculated is preferentially put into the delivery path.

Continue the calculation according to the above steps until all nodes are inserted into the completion of the route representation algorithm calculation.

4.1.3 The design of C-W Saving algorithm

When the algorithm is selected to solve the distribution path optimization model of the E-commerce fresh cold chain studied in this paper, considering the limited load capacity of the electric vehicle, the service of the fresh warehouse or distribution node to the customer group is direct delivery from point to point. The algorithm is designed as follows:

Set the base point. Set the fresh warehouse as the base point and set it as P_{m+1}, Set the remaining m distribution points as nodes $P_1, P_2, P_3 \ldots p_m$, connecting the base points P_{m+1} to all the nodes will get m delivery routes.

Taking the base point P_{m+1} as the center, daw a circle with the maximum travel distance d_{max} when the electric tricycle is fully loaded., Set t customer groups covered in the circle area as nodes $X_1, X_2, \ldots X_t$, Calculate the total cost of the base point P_{m+1} for each customer group X_t covered in a circular area using an electric tricycle for individual service,and connecting the base points P_{m+1} in turn X_t to obtain t distribution routes;

All nodes are connected in pairs, represented by real pairs（i, j）, and the formula for saving distance values is: $S(i, j) = C_{Oi} + C_{oj} - C_{ij} (i \neq j)$,a table of savings distances between nodes and nodes can be derived.

（4）Pick a node as the first access customer on the delivery route. The method of selection is: when deliver the goods from the fresh warehouse to the distribution node, calculate the total cost of arrival to each distribution network.（$Z_1, Z_2, Z_{3\dots} \dots Z_m$）.The node with the smallest total transportation cost Z_i is set as the first customer to be delivered on the delivery route. P_o 。

（5）Search for the node which is closest to P_o , that is $S(m+1, j) = C_{m+1,0} + C_{m=1j} - C_{Oj}$, select the node that meets the largest saving value. ， count the node as the second distribution node on the route and get the first delivery route.

（6）After the first delivery path is obtained, continue to follow steps (4) and (5) to determine the second delivery path.

（7）Step (6) is repeated until all the nodes are inserted into the route, and then the m distribution nodes P_i are sequentially connected with the remaining customer groups X_j in the respective delivery areas, and finally the optimal delivery scheme is obtained.

4.2 Case study

This paper selects the fresh cold chain distribution of a large-scale e-commerce logistics in Suzhou as the case analysis object. Because the company has too many distribution nodes and warehouses in Suzhou, this paper takes the two-echelons logistics system containing 10 distribution nodes in the central and eastern part of Suzhou for experimentations, Since the distribution distance between the customer and the customer is too short, the transportation and cooling costs are too low, which can be neglected. Therefore, the customers of each nodeare divided into three customer groups according to the demand to vertify the correctness of the model and algorithm .

The wage of the truck driver is 400 yuan / day, the wage of the electric tricycle driver is 233 yuan / day, the driving speed of the truck is 40km / h, the driving speed of the electric tricycle is 20km / h,each node receives two shipments per day, each time receiving 50 single items, each weighing 5kg;The maintenance cost of the truck is 21.6 yuan / day; each electric tricycle is replaced twice a year, each time is replaced by 50 yuan; The transportation cost per kilometer when each truck is fully loaded is 4.10 yuan/km, and the transportation cost of each electric tricycle at full load is 0.1416 yuan/km.

There are two different types of vehicles in the fresh warehouse and distribution node, the “Dongfeng Tianjin”7.6-meter box-type constant-temperature truck and the 1.5-meter enterprise-specific van-type electric tricycle. The specific parameters are shown in Table 1, Table 2. The relevant parameters of various costs are shown in Table 3. The distance between distribution nodes is shown in Table 4.

Table 1 Electric tricycle related parameters

Brand	Enterprise-specific power train	For people	General purpose
Wheel diameter	other	Commodity origin	Xuzhou Jiangsu
Voltage	60v	Vehicle size	2900*1000*170
Gross weight of goods	180kg	Car size	1500*1000*1000
Style	tricycle	Battery rated capacity	38A
Full load theory life	40km		

Table 2 Truck related parameters

Typle	Multipurpose truck	Load weight heavy	(Total mass > 15 tons) T
use	cargo	engine model	ISB180 40
model	5160XYKBX1A	Exterior color	Silver
Drive form	Manual	total weight	16000kg
Gearbox type	DF6F900	Overall dimensions	9995×2550×3960mm
Cargo interior size	7500×2400×2600mm	Number of tires	6
Brand	Dongfeng		

Table 3 Related parameters of various costs

parameter	Parameter value	parameter	Parameter value
R， r	2	e	18yuan/kg
ξ_i	Take0.25	λ	0.0002/h
Cmax	15000kg	θ^*	0.5826L/km
cmax	180kg		

Table 4 Distance between distribution nodes

Dis (km)	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A0	0	32.2	41.0	53.6	37.5	30.8	21.7	30.9	25.6	26.6	23.8
A1	32.2	0	13.3	24.7	9.7	10.1	13.2	4.7	6.4	6.2	9.7
A2	41.0	13.3	0	12.3	3.8	10.1	19.9	10.7	16.3	18.6	22.3
A3	53.6	24.7	12.2	0	15.7	22.4	32.2	23.1	28.7	30.7	34.2
A4	37.5	9.7	3.8	15.7	0	6.9	16.3	6.9	12.3	15.2	18.9
A5	30.8	10.1	10.1	22.4	6.9	0	9.5	5.1	8.1	12.3	15.2
A6	21.7	13.2	19.9	32.2	16.3	9.5	0	10.8	7.1	10.9	11.8
A7	30.9	4.7	10.7	23.1	6.9	5.1	10.8	0	5.3	8.1	11.7
A8	25.6	6.4	16.3	28.7	12.3	8.1	7.1	5.3	0	4.0	6.5
A9	26.6	6.2	18.6	30.7	15.2	12.3	10.9	8.1	4.0	0	3.5
A10	23.8	9.7	22.3	34.2	18.9	15.2	11.8	11.7	6.5	3.5	0

In this paper, the route is re-optimized by using c, w algorithm combined with the above related parameters. The optimization route is shown in Figure c. The costs before and after optimization are shown in Table 5.

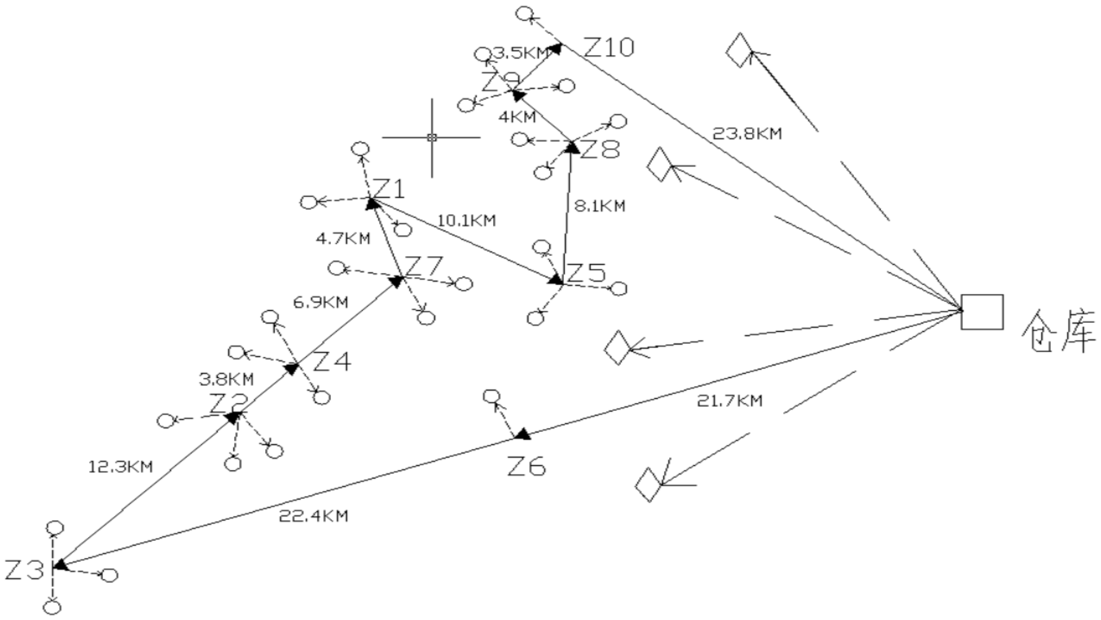

Figure c. Optimized delivery route

Fig. 5 Cost before and after Route Optimization

		Fixed cost	Refrigeration cost	Transportation cost	Cost of cargo damage	Total cost	Total cost within a Duty cycle
Before optimization	Wagon	139.57	2640.625	165.7	15.052	4165.177	12790.571
	Electro-tricycle	7007.3	1868.75	16.215	0.129	8892.394	
After optimization	Wagon	139.57	985.562	143.695	5.64	1541.137	11128.253
	Electro-tricycle	7007.3	2823.16	23.2932	0.663	9869.116	

It can be seen from Fig. c that the customer groups of A6 and A10 located between the warehouse and its own outlets are directly served by the warehouse after the redistribution of the distribution system. Compared with the total mileage of 438.7km distributed at a traditional single point between the outlets, each outlet is distributed sequentially by a truck, with a total mileage of 286.5km, which is reduced by 34%, achieving obvious optimization effect, and thus being the main reason for the reduction of the total cost.

From Table 5, it can be seen that in addition to the fixed cost, the refrigeration cost of trucks has been reduced by 60% due to the reduction of distribution mileage under the new two-echelon logistics system. And the costs of transportation and cargo damage have also been reduced to a certain extent, by 13.3% and 66.7% respectively. The refrigeration cost, transportation cost and cost of cargo damage all have been increased considerably, with 51.3%, 43.7% and 500% respectively for the increase in distribution mileage of electric vehicles. However, as the cost of cargo damage is too small, the impact of its substantial increase or decrease can be ignored. And the total cost of the new two-stage logistics system in one Duty cycle is reduced by 12.9% before and after the final optimization.

Fig. c and Table 5 show that e-commerce enterprises can reduce the total cost of the fresh food in two-stage logistics distribution system through route optimization. If e-commerce enterprises want to expand their fresh-food market, they must strengthen the cooperation of participants in their two-stage system with the optimization of distribution routes and the change of traditional distribution concepts for reducing the total cost of distribution and further making profits.

5. Conclusion

This paper studies the fresh food distribution in two-level logistics system of the e-commerce. Firstly, it points out that in recent years, with the change of the location and layout of consumer groups, the point-to-point single-line distribution of each level in the traditional two-level logistics system has greatly increased the cost, which is not conducive to the further profit of the e-commerce fresh food market. Therefore, the distribution mileage and time, fresh goods loss, vehicle maintenance cost, and driver's salary, etc. are considered in this paper to establish a fresh goods loss distribution model with the objective of minimizing the sum of fresh goods loss and vehicle cost, which improves the traditional C/W algorithm and optimizes the distribution route of the existing two-level system according to the model. Finally, the actual case of fresh goods distribution in an e-commerce company in Suzhou proves that the model not only saves the total distribution mileage and reduces the number of distribution routes, but also reduces the total cost according to the model by 12.9% compared with the total cost under the traditional distribution mode.

This paper only takes the distribution of fresh goods at the same temperature and the same customer demand in consideration. In reality, the temperature is required to be inconsistent for various kinds of fresh goods. Therefore, in the next phase of research, the dynamics of customer demand and satisfaction will be taken into account to conduct in-depth research on the multi-temperature heterogeneous vehicle model.

References

[1] Gao, L. L., & Jr, E. P. R. (1994). Uncapacitated facility location: general solution procedure and computational experience. European Journal of Operational Research, 76(3), 410-427.

[2] Jr, E. P. R., & Swink, M. L. (1995). A comparative model of facility network design methodologies. Journal of Operations Management,13(3), 169-181.

[3] Bruns, A. (1998). A Local Search Heuristic for the Two-Stage Capacitated Facility Location Problem. Advances in Distribution Logistics. Springer Berlin Heidelberg.

[4] Crainic, T. G., Perboli, G., Mancini, S., & Tadei, R. (2010). Two-echelon vehicle routing problem: a satellite location analysis. Procedia - Social and Behavioral Sciences, 2(3), 5944-5955.

[5] Perboli, G., Tadei, R., & Tadei, R. (2010). New families of valid inequalities for the two-echelon vehicle routing problem. Electronic Notes in Discrete Mathematics, 36, 639-646.

[6] Wang, M., Tian, X., Shan, C., & Wu, S. (2011). Hybrid ant colony optimization algorithm for two echelon vehicle routing problem. Procedia Engineering, 15, 3361-3365.

[7] Dondo, R., Méndez, C. A., & Cerdá, J. (2011). The multi-echelon vehicle routing problem with cross docking in supply chain management. Computers & Chemical Engineering, 35(12), 3002-3024.

[8] Wang, Y., Ma, X., Xu, M., Liu, Y., & Wang, Y. (2015). Two-echelon logistics distribution region partitioning problem based on a hybrid particle swarm optimization–genetic algorithm. Expert Systems with Applications, 42(12), 5019-5031.

[9] Wang, Y., Ma, X., Liu, M., Gong, K., Liu, Y., & Xu, M., et al. (2017). Cooperation and profit allocation in two-echelon logistics joint distribution network optimization. Applied Soft Computing.

[10] Litvinchev, I. S., Mata, M., & Ozuna, L. (2012). Lagrangian heuristic for the two-stage capacitated facility location problem. Applied & Computational Mathematics, 11(1), 137-146.

[11] Hasan, & Tayyaba. (1998). Acceleration of wound healing by photodynamic therapy.

[12] Govindan, K., Jafarian, A., Khodaverdi, R., & Devika, K. (2014). Two-echelon multiple-vehicle location–routing problem with time windows for optimization of sustainable supply chain network of perishable food. International Journal of Production Economics, 152(2), 9-28.

[13] Soysal, M., Bloemhof-Ruwaard, J. M., & Bektaş, T. (2015). The time-dependent two-echelon capacitated vehicle routing problem with environmental considerations. International Journal of Production Economics, 164, 366-378.
[14] Li, H., Zhang, L., Lv, T., & Chang, X. (2016). The two-echelon time-constrained vehicle routing problem in linehaul-delivery systems. Transportation Research Part B, 94, 169-188.