ISSN: 2688-9323

Research on Collaborative Delivery of Electric Unmanned Vehicles

Shaowei Xing

School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing,400065, China

Abstract

This paper studies the problem of coordinated distribution with electric unmanned vehicles as vehicles in order to reduce the cost of terminal distribution and reduce the duplication of distribution paths among multiple distribution entities under the background of urban terminal distribution. A two-stage optimization model is designed, and a solution model with tabu search algorithm as the main algorithm is designed. Different sets of calculation examples are compared with traditional transportation methods to prove the effectiveness of the model. The results show that the collaborative delivery model can effectively reduce the overall delivery cost at the end, which proves the effectiveness of the model.

Keywords

Electric Unmanned Vehicle; Vehicle Routing Problem; Collaborative Delivery.

1. Introduction

The "last mile" is the last link of the entire logistics distribution. This link requires a large number of goods to be distributed, the environment is complex, and the distribution paths are overlapping. The data shows that the cost and time spent in the end distribution link account for 30% of the entire distribution operation. the joint delivery between multiple entities at the end is a mode that can effectively reduce the route duplication problem, and new types of vehicles will also provide a new way to solve this problem in the future. On February 24, 2020, the National Development and Reform Commission and other 11 departments jointly issued the "Intelligent Vehicle Innovation Development Strategy" clearly put forward the strategic goal of building China's standard intelligent vehicles and realizing the power of intelligent vehicles. With the practical use of 5G, the network hardware environment required for unmanned vehicles has gradually matured. During the epidemic, JD’s L4-level unmanned delivery vehicle "Dabai" undertook 50%-70% of orders from Wuhan Ninth Hospital; Meituan also The deployment of unmanned delivery vehicles around the Meituan grocery shopping site in Beijing to deliver to communities far away indicates that this unmanned delivery vehicle has begun to become practical.

Many scholars have conducted research to solve the problem of coordinated delivery at the end. Yang Jun [1] In the article Research on the site selection and route optimization of the electric vehicle logistics distribution system, this paper puts forward the problem of the site selection and distribution route optimization of the electric vehicle logistics distribution system, establishes an integer programming model, and designs Tabu search-Improve the Clarke-Wright saving two-stage heuristic algorithm to solve the model; Shao Sai [2] in his article on the analysis of the operation characteristics of pure electric logistics vehicles and the study of the optimization problem of distribution routes, studied the pure consideration of dynamic travel time. The vehicle routing problem of electric logistics vehicles and the vehicle routing problem of pure electric logistics vehicles considering dynamic demand. Dynamic driving time

ISSN: 2688-9323

is based on the dynamics of traffic information (predicting traffic conditions with probability, charging waiting conditions, etc.), according to the technical and operating characteristics of pure electric logistics vehicles, comprehensively considering load constraints, time window constraints, mileage constraints, and charging requirements And the driving speed, the EVRPVTT problem model with the smallest total cost is established. And apply the genetic algorithm combined with exhaustive method to solve the model. Li Jie [3] in the article on electric vehicle configuration and route integration optimization for e-commerce terminal logistics distribution,. Aiming at the problems of large scale of terminal logistics distribution and limited electric vehicle cargo capacity and mileage in e-commerce environment, an integrated optimization model of electric vehicle configuration and path planning for e-commerce terminal logistics distribution is established, and a dual strategy based on the list of neighboring cities is proposed. The ant colony algorithm realizes the integrated optimization of the electric vehicle configuration and distribution path of logistics distribution. Wang Yongcong [4] in his master's thesis mainly combined the characteristics of pure electric vehicles and abstracted the EVRP problem as a VRP problem based on social charging network with vehicle capacity constraints, single charge mileage constraints, and single vehicle daily mileage constraints. Jie Wanchen [5] considered the maximum battery capacity, battery charging rate, power consumption rate, maximum load, fixed cost and variable cost of different types of electric logistics vehicles, and established a multi-vehicle EVRP problem model, and used it The branch and bound algorithm is used to solve the problem. Lin [6] and others focused on the impact of vehicle load on electricity consumption, and proposed the EVRP problem that minimizes the sum of driving costs and energy costs; Goeke and Schneider [7] applied adaptive large-scale domain search algorithms to solve traditional fuel vehicles The VRP problem of the hybrid fleet of electric vehicles and electric vehicles, which considers driving speed, gradient and load capacity to establish an energy consumption model that is more in line with actual needs; Yang and Sun [8] established the location-path problem of electric vehicle switching stations with mileage constraints. The integer programming model of the traditional LRP problem is divided into four stages to apply different algorithms (such as improved scanning algorithm, adaptive large-scale domain search algorithm, greedy algorithm, combined with tabu search improved economy method) to solve; Bruglieri[9], etc. Establish the EVRP problem of minimizing the total time including driving time, waiting time and charging time and minimizing the number of vehicles, in which vehicles are allowed to be partially charged at the charging station; Liu Ming [10] et al. commented on the traditional point-to-point distribution model Analyze the hub radiation model, construct a hybrid collaborative delivery model to take into account the advantages of the two models, and then establish the hybrid collaborative delivery model function model and give a specific solution heuristic search algorithm. Based on the theory of virtual enterprise and resource integration, Li Ding [11] put forward a model for 3PL companies to implement collaborative delivery in a virtual environment,and used Automod simulation software to conduct a simulation study on the model, and finally concluded that collaborative delivery can increase the load of a single vehicle. Reducing logistics costs, and the advantages of effective use of transportation resources. Wang Xiaobo [12] believed that the distribution particularity in the collaborative distribution environment was solved by an improved two-stage algorithm: in the first stage, the customer group was divided into several regions by K-means clustering method, and the scanning algorithm was used to decompose each region. It is divided into several small-scale subsets that meet the constraints; in the second stage, the customer points in each group are the line optimization problems of individual TSP models, and the improved genetic algorithm is used to optimize the solution. In order to eliminate the bullwhip effect in terminal distribution, Lee [13] et al. Stanislaw Iwan [14]and others conducted in-depth research on information sharing and terminal distribution solutions. The research of terminal distribution is gradually moving towards the combination

ISSN: 2688-9323

of practicality and informationization. Liu [15]et al. proposed a mathematical programming model and its corresponding graph theory model,and designed a two-stage greedy algorithm to solve the actual large-scale logistics distribution problem, thereby minimizing the no-load operation of vehicles. Linet Özdamar et al. designed a multi-level clustering algorithm to group demand points into smaller clusters, and plan specific paths within the clusters, and the clusters are independent of each other to obtain a better route plan.

At present, most scholars study the electric vehicle path planning (EVRP) problem, which focuses on the path optimization under the constraints of electric vehicle endurance, time window and load, and most of them are single distribution center problems, and the distribution path is closed loop; there are few studies. In the unmanned electric vehicle distribution, there is no need to return to the original distribution center, but the semi-open path planning problem of returning to any distribution center nearby. At present, regarding the problem of end distribution coordination, the coordination problem of most researchers is that there are multiple distribution centers but the distribution items are uniform The coordination problem of chemical goods, or the coordination problem of different distribution centers of the same enterprise in the distribution stage, and less involve the problem of distribution after coordinated deployment among multiple distribution entities.

2. Method

2.1. Problem Description

The problem of coordinated distribution at the end of electric vehicles studied in this paper can be described as that there are multiple different distribution entities in the same area, each distribution entity has a warehousing function, and each distribution entity has a certain number of shared unmanned delivery vehicles. To complete the transportation tasks of distribution and deployment, the location of each end demand point and the quality of the goods that need to carry out the distribution business are known. After the distribution task is completed, the distribution unmanned vehicle can return to any distribution entity nearby without returning to the starting point; During the delivery process, when the power of the unmanned vehicle is insufficient to complete the remaining mileage, a charging plan needs to be deployed, and the delivery of the next customer node can be continued when it is fully charged. Through the combination of deployment and distribution, the route duplication of the end distribution is reduced to the greatest extent, so that the total cost is the lowest. The total cost includes the fixed delivery cost and driving cost of the delivery of unmanned vehicles, the fixed delivery cost and travel cost of the deployment vehicles, and the charging cost of the delivery of unmanned vehicles.

Compared with the general electric vehicle routing problem and the double-decker vehicle routing problem, this article has the following characteristics

1. The delivery unmanned vehicle in the collaborative delivery area is in a shared state, so it is not necessary to return to the original starting point after the delivery is completed;

2. There is a process of allocating goods between different distribution entities, that is, when it is determined that a certain item of goods is distributed by the distribution center where it is not located, it needs to be deployed from the distribution entity where it is located to the distribution entity that performs the distribution.

2.2. Variable and Parameter Definition

C_0 : Total cost

C_1 : Delivery cost

C_2 : Deployment cost

C_3 : Charging cost

u_1 : Distribution unit distance cost of distribution center (yuan/km)
u_2 : The unit distance cost allocated between distribution centers (yuan/km)
u_3 : Single charge cost (yuan/h)
f_1 : The cost of a single dispatch of vehicles in the distribution center (yuan)
f_2 : The cost of a single vehicle dispatched by the distribution center (yuan)
M : The collection of distribution centers to which the end demand point begins to belong
M' : The distribution center set to which the end demand point is allocated (starting point)
M'' : The collection of distribution centers to which the end demand point is allocated (end point)
F : Collection of charging stations
N_m : The collection of end demand points belonging to distribution center m
$N_m^{m'}$: A collection of end demand points belonging to distribution center m but assigned to distribution center m′
K : The collection of vehicles in the delivery stage
K' : Vehicle collection in the deployment phase
d_{ij} : The driving distance between point i and point j
q_j : The weight of the goods at demand point j
$W_{\max}$: The weight of the goods at demand point j
$W'_{\max}$: The loading capacity of the delivery vehicle
x_{ijk} :0-1 decision variable, when the vehicle travels from point i to point j, its 1, otherwise its 0
y_{jk} :0-1 decision variable, when the vehicle k is charged at point j, it is 1, otherwise it is 0
$d_{mm'}$: The distance between the distribution center m and m′

2.3. Distribution Stage Model

$$MinC_0 = C_1 + C_2 + C_3 \quad (1)$$

$$C_1 = f_1 \sum_{k\in K} \sum_{i\in M'} \sum_{j\in N_m^{m'}} x_{ijk} + u_1 \sum_{k\in K} \sum_{i\in M'\cup N_m^{m'}} \sum_{j\in N_m^{m'}} x_{ijk} d_{ij} \quad (2)$$

$$C_3 = u_3 \sum_{j\in F} y_{jk} \quad (3)$$

$$\sum_{i\in M'\cup N_m^{m'}} x_{ijk}=1 \quad \forall j \in N_m^{m'} \quad \forall k \in K \quad (4)$$

$$\sum_{\forall i\in M'\cup N_m^{m'}} x_{ijk}= \sum_{\forall p\in M'\cup N_m^{m'}} x_{jpk} \quad \forall j \in N_m^{m'} \quad \forall k \in K \quad (5)$$

$$x_{m'jk} = 1 \quad \forall j \in N_m^{m'} \cup m'' \quad \forall k \in K \quad (6)$$

$$x_{im''k} = 1 \quad \forall j \in N_m^{m'} \cup m' \quad \forall k \in K \quad (7)$$

$$D_{jk} = [D_{ik}(1 - y_{ik}) + y_{ik}D_{\max} - D_{ij}]x_{ijk}$$

$$\forall j \in \sum_{m \in M} N_m \cup F \cup M'' \quad \forall i \in \sum_{m \in M} N_m \cup F \cup M' \quad \forall k \in K \tag{8}$$

$$D_{jk} \geq 0 \quad \forall j \in \sum_{m \in M} N_m \cup F \cup M'' \quad \forall k \in K \tag{9}$$

$$Dm'k = D\max \quad \forall k \in K \tag{10}$$

$$\sum_{i \in M' \cup N_m^{m'}} \sum_{j \in N_m^{m'}} x_{ijk}q_j \leq W_{\max} \quad \forall k \in K \tag{11}$$

$$y_{jk} \leq z_j \quad \forall j \in \sum_{m \in M} N_m \cup F \cup M'' \quad \forall k \in K \tag{12}$$

$$x_{ijk} = \{0,1\} \quad \forall j \in N_m^{m'} \cup m'' \quad i \in M' \cup N_m^{m'} \quad \forall k \in K \tag{13}$$

$$y_{jk} = \{0,1\} \quad \forall j \in \sum_{m \in M} N_m \cup F \cup M'' \quad \forall k \in K \tag{14}$$

Equation (1) indicates that the total cost is composed of distribution cost, deployment cost and charging cost; Equation (2) indicates that the distribution cost is determined by the number of vehicles dispatched and the total mileage; Each demand point has vehicles for service; Equation (5) expresses the conservation of traffic at the service point, ensuring that vehicles leave after delivery; Equations (6) and (7) ensure that vehicles depart from the distribution center and finally return to the distribution center; Equation (8)) And (9) are expressed as mileage constraints, so that the remaining mileage of the vehicle to any node is not 0, and the delivery vehicle will proceed along the shortest path; equation (10) indicates that the power of the delivery vehicle is full when starting from the distribution center; equation (11) means that the load of the delivery vehicle at any node does not exceed the capacity of the vehicle; formula (12) means that the vehicle can only replenish power at the charging station; formula (13) is a 0-1 variable, which is expressed as the initial route; formula (14) Is a 0-1 variable, expressed as the initial charging plan.

2.4. Model of Deployment Stage:

In the deployment stage, the distribution path obtained in the distribution stage needs to be re-assigned, the distance between the end demand points and the distance between the distribution center and the end demand point are re-assigned, and the original problem is transformed into a deployment problem, which is essentially equal to the difference between the distribution centers. The mutual deployment of goods between. Re-assign the distance between the end demand points according to the following two conditions.

(1) Set the distance between all the end demand points in the collection N_m to 0; that is, because the goods have not been dispatched, they are still in the warehouse, so the mutual distance between the goods belonging to a certain delivery subject is 0;

(2) At time, let all the distances to and be 0, and q_j=0, j∈ $N_m^{m'}$; at time, let all the distances to m' and $N_m^{m'}$ be $d_{mm'}$. That is to say, all the goods that belong to the distribution entity m and are also distributed by the distribution center m', the distribution distance is set to 0, meaning that

the deployment distance is 0, and the demand is set to 0, that is, no deployment is required; all are attributable to the distribution The main body m, but the goods delivered by the delivery center m', the delivery distance is set to the distance between m and m', that is, the deployment distance is the distance between m and m'. (The delivery subject indicates the attribution attribute of the goods themselves, and the distribution center indicates the delivery attributes of the goods, but the delivery subject and the distribution center with the same number are in the same place, and the marks are distinguished.)

$$C_2 = f_2 \sum_{k'\in K'} \sum_{i\in M'} \sum_{j\in N_m^{m'}} x_{ijk'} + u_2 \sum_{k'\in K'} \sum_{i\in M'\cup N_m^{m'}} \sum_{j\in N_m^{m'}} x_{ijk'} d_{ij} \tag{15}$$

$$\sum_{i\in M'\cup N_m^{m'}} x_{ijk'} = 1 \quad \forall j \in N_m^{m'} \quad \forall k' \in K' \tag{16}$$

$$\sum_{\forall i\in M'\cup N_m^{m'}} x_{ijk'} = \sum_{\forall p\in M'\cup N_m^{m'}} x_{jpk'} \quad \forall j \in N_m^{m'} \quad \forall k' \in K' \tag{17}$$

$$x_{m'jk'} = 1 \quad \forall j \in N_m^{m'} \cup m" \quad \forall k' \in K' \tag{18}$$

$$x_{im"k'} = 1 \quad \forall j \in N_m^{m'} \cup m' \quad \forall k' \in K' \tag{19}$$

$$\sum_{i\in M'\cup N_m^{m'}} \sum_{j\in N_m^{m'}} x_{ijk'} q_j \le W'_{\max} \quad \forall k' \in K' \tag{20}$$

$$x_{ijk'} = \{0,1\} \quad \forall j \in N_m^{m'} \cup m" \quad i \in M' \cup N_m^{m'} \quad \forall k' \in K' \tag{21}$$

Equation (15) represents that the deployment cost is composed of the fixed delivery cost of the deployment vehicle and the travel cost of the deployment vehicle; Equations (16) and (17) represent that all goods have been found, and each piece of goods has one and only one Formula (18) and (19) ensure that each dispatched vehicle departs from the distribution center and returns to the distribution center; Formula (20) means that the distribution vehicle can ensure that its load does not exceed the vehicle load at any node. Content; Formula (21) is a 0-1 variable, which represents a virtual cargo dispatching route.

3. Algorithm Design

This paper divides the generation of the solution in the distribution stage into two stages. First, heuristic algorithm and tabu search algorithm are used to determine the initial attribution assignment, and determine the end service point corresponding to each distribution center. Then use the tabu search algorithm to plan the path of the end demand points of each distribution center service.

3.1. Attribution

(1) Generate initial solution

Because the final solution result and solution speed of the tabu search algorithm largely depend on the quality of the initial solution, this paper generates the heuristic rules of this stage according to the ratio of the end demand point demand and the distribution distance from the

ISSN: 2688-9323

distribution center. The initial solution is that the closer to the distribution center and the larger the distribution volume, the sooner the demand point will be met.

Step1: Calculate the Euclidean distance between each distribution body and each end distribution point d_{ij};

Step 2: Generate q_j/d_{ij} matrix Q = $\begin{matrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{matrix}$, the rows represent m distribution centers, and the columns represent all n end distribution points.

Step3: Take the maximum value $r_{i'j'}$ of r_{ij} in the demand/distance matrix Q, check whether the capacity of the delivery vehicle of the distribution center i' can complete the delivery task of the end delivery point j', and if so, set the delivery point j' is assigned to the delivery subject i' for delivery, and the column where the delivery point j' is located is deleted. If it cannot be completed, the $r_{i'j'}$ point is set to zero.

Step 4: Repeat Step 3 until all the distribution points are assigned to each distribution center, and then the initial distribution point attribution plan is obtained.

(2) Taboo search algorithm logic

Define two operations of "move" and "swap". A and B refer to two distribution entities, "mobile" refers to changing one or more distribution points belonging to distribution entity A to distribution entity B for distribution; "swap" means that it will be attributed to distribution entities A and B One or several distribution points of the company are exchanged.

Apply the tabu search algorithm to optimize the allocation plan, the specific steps are as follows:

Step1: Generate the Euclidean distance table between all the delivery subjects and the delivery point, 1^A means that the No. 1 delivery point is delivered by the delivery subject A;

Step2: "Move" operation. Calculate the distance between each delivery point belonging to the delivery entity A and the delivery entity B, and "move" the delivery point closest to the delivery entity B to the delivery entity B for service, and determine the remaining capacity of the delivery vehicle of the delivery entity B Whether the delivery requirements at this point can be met, if it can be met, the operation will be executed, if it cannot be met, the current operation will be abandoned;

Step3: "Swap" operation. Find out the several distribution points that are closest to B among the distribution points belonging to the distribution body A, and the several distribution points that are the closest to A among the distribution points belonging to the distribution body B. Determine whether the total delivery vehicles of the delivery points serviced by the two delivery entities exceed the upper limit of the capacity of the respective delivery vehicles after the implementation of "swap", if it exceeds, execute the operation, otherwise, abandon the operation.

Step4: When a good enough solution appears in the neighborhood, use the contempt rule to replace the original optimal solution with this solution as the current optimal solution, and put the taboo object corresponding to the previous optimal solution into the taboo table, and lift the ban Objects that are banned for longer than the taboo length, then go to Step 6, if the contempt criterion is not activated, go to Step 5;

Step5: Evaluate each feasible solution in the neighborhood, select the best solution among the feasible solutions as the current optimal solution, and replace the taboo object corresponding to the solution for the taboo object that entered the taboo table earliest.

Step6: Judge the termination condition, if yes, stop, otherwise go to Step2.

ISSN: 2688-9323

3.2. Distribution Route Planning

(1) Coding

The vehicle used in this study is an electric unmanned vehicle. Not only must we consider the issue of delivering to the distribution point, but also the issue of going to the charging station to charge when the remaining mileage is insufficient due to the distance constraint of the electric vehicle. The problem needs to be able to show the order in which vehicles visit the stations, which can be coded in the order of natural numbers. The codes of m distribution centers are 1,...,m, there are a total of n distribution points, and the distribution point numbers are m+1,... ,m+n, each distribution center is rehearsed in sequence according to the distribution points allocated in the attribution distribution stage, and then inserts the corresponding distribution center according to the load constraints of the distribution unmanned vehicle and the distribution volume of each distribution point to ensure delivery The total amount of delivery and collection between centers does not exceed the load constraint of the unmanned vehicle. For example, there are 2 distribution centers and 20 terminal demands, which are divided into (3 5 7 9 11 13 15 17 19 21) and (4 6 8 10 12 14 16 18 20 22) using load constraints to insert the corresponding distribution after the assignment the center gets (1 3 5 7 9 11 13 1 1 15 17 19 21 1) and (2 4 6 8 10 12 2 2 14 16 18 20 22 2）, indicating that there are 2 distribution centers, and 4 unmanned delivery vehicles are 20 A distribution point service.

(2) Decoding

Decoding is the reverse calculation of encoding. The end vehicle used in this article is an unmanned delivery vehicle. Therefore, the above encoding needs to determine the power on the sub-path once. Once the power is not enough to reach the nearest node from the next node to the next node. Station, go to the charging station closest to the current node to charge. For example, in the above example, if there are r terminal charging stations, the numbers are m+n+1, m+n+2,...,m+n+r. For example, 2 distribution centers send 4 vehicles to 20 distribution points If you need to visit 2 charging stations during the service, the codes are(1 3 5 7 9 25 11 13 1 1 15 17 19 21 1)and(2 4 6 8 10 28 12 2 2 14 16 18 20 22 2), then The decoded vehicle path is:

Path 1: 1-3-5-7-9-25 (charging station)-11-13-1

Path 2: 1-15-17-19-21-1

Path 3: 2-4-6-8-10-28 (charging station)-12-2

Path 4: 2-14-16-18-20-22-2

Get the initial feasible solution through encoding and decoding;

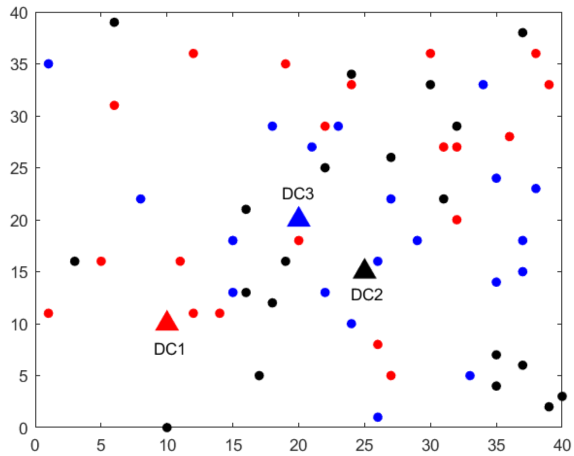
4. Simulation Analysis

4.1. Overview of Calculation Examples

There are three delivery companies in a certain area, the coordinates are [10,10], [20,20], [25,15]. On a certain day, the three delivery companies all have 20 delivery tasks in the morning. These delivery points They are all distributed within the urban area of 40kmx40km. This article assumes that the distance between the distribution points is Euclidean distance, and the distribution vehicles deliver at an average speed. The coordinates of the distribution points, the distribution centers to which the distribution points belong, and the distribution quality of each distribution point are as follows Shown. At present, the three delivery companies adopt the joint delivery model described in this article. Each delivery company has 5 delivery unmanned vehicles and 1 dispatching vehicle at the site before the start of the mission today, and the delivery cost of the delivery unmanned vehicle is 50 yuan. Per vehicle, the maximum driving distance is 60km, the driving cost is 1 yuan/km, the maximum load capacity is 100kg, and the average driving speed is 30km/h; the dispatch cost of the dispatched vehicle is 100

ISSN: 2688-9323

yuan/vehicle, and the maximum driving distance is 200km. The cost is 2 yuan/km, the maximum load capacity is 200kg, and the average driving speed is 40km/h.



Figuer 1. Coordinate map of distribution center and distribution point

There are a total of 30 charging stations in the urban area. The locations of the charging stations are shown in Figure 2, and the detailed coordinates are shown in Table 2. The charging time for unmanned vehicles is 30 minutes each time, and the charging fee is 15 yuan/time. The coordinates of the charging station are shown in the following table; in order to prevent vehicles from being too concentrated at a certain distribution station, a virtual parking system is set up, and each distribution center is unmanned. There are no more than 10 vehicles at most, and the average waiting time after the delivery of goods arrives at the delivery point is 10 minutes;

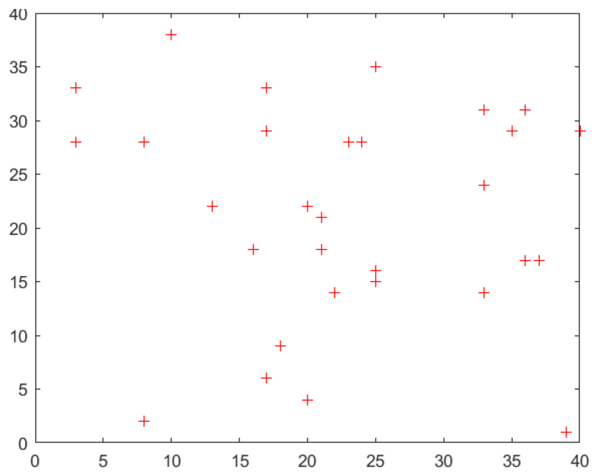


Figure 2. Location of charging pile

4.2. Simulation Experiment Analysis

This mode is the distribution mode studied in this article. The cost of delivering unmanned vehicles is 50 yuan/vehicle, the maximum driving distance is 60km, the driving cost is 1 yuan/km, the maximum load capacity is 100kg, and the average driving speed is 30km/ h; The cost of dispatching the vehicle is 100 yuan/vehicle, the maximum driving distance is 200km, the driving cost is 2 yuan/km, the maximum load capacity is 200kg, and the average driving speed is 40km/h. In this stage, the improved algorithm of the tabu search algorithm is used to optimize the two phases of distribution and deployment. The number of domain searches is set to 100 times, the maximum number of iterations is 1000, and the length of tabu search is 80. The iteration curve is shown in Figure 3, and the road map is shown in Figure 4. A total of 6 distribution routes are generated, and the total distribution cost is 776 yuan.

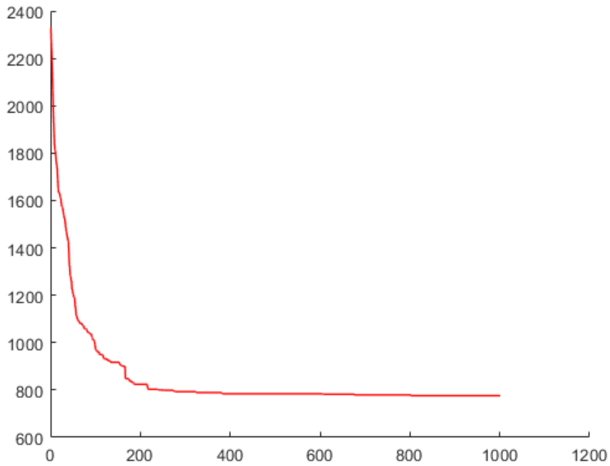


Figure 3. Varying distribution optimization iterative curve

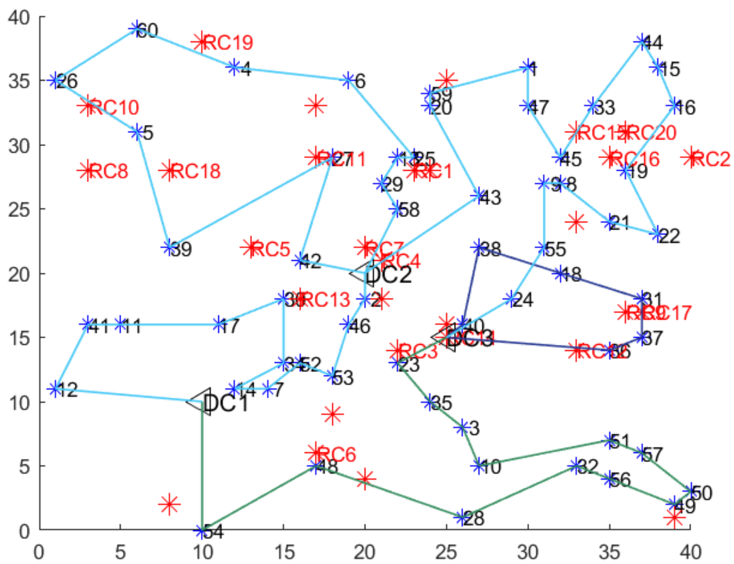


Figure 4. Change allocation roadmap

Table 1. Route table of each delivery vehicle

	Access sequence
Vehicle1	2→5→49→33→45→42→8→7→63→29→44→15→1
Vehicle2	2→32→30→9→23→62→4→19→22→25→34→27→3
Vehicle3	3→26→56→55→37→10→51→17→20→14→1
Vehicle4	2→46→48→11→58→41→54→35→31→57→1
Vehicle5	3→43→21→24→12→36→18→47→50→28→16→61→2
Vehicle6	3→39→40→60→53→52→59→13→6→38→3

In this calculation example, the calculation results of the deployment stage are shown in Table 2, and the deployment route map is shown in Figure 5.

ISSN: 2688-9323

Table 2. Allocation task list of each distribution center

Deployment point	Acceptance point	Allocation amount
1	2	68
1	3	74
2	3	85
3	2	92

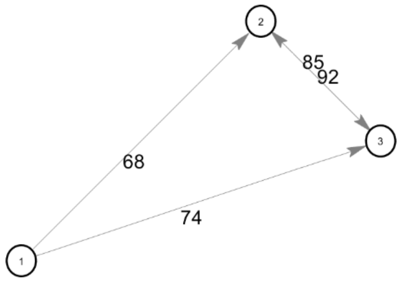


Figure 5. Allocation route map between distribution centers

Table 3. Allocation route table

Starting point of deployment	Number of tasks	Loading and unloading (1 is loading, 2 is unloading)	Loading and unloading
2	0	0	0
2	3	1	85
1	1	1	68
1	2	1	74
3	2	2	74
3	3	2	85
3	4	1	92
2	1	2	68
2	4	2	92
2	0	0	0

It can be seen from the table that there is only one deployment vehicle in this example, and the driving path is 2-1-3-2. The deployment vehicle starts from distribution center 2 and loads 85kg of goods that need to be transported to distribution center 3; then arrives at the distribution center 1. Load 68kg of goods that need to be transported to distribution center 2 and 74kg of goods that need to be transported to distribution center 3; then arrive at distribution center 3, unload 85kg of goods from distribution center 2 and 74kg of goods from distribution center 1, and load The 92kg of goods that need to be transported to distribution center 2 are removed; then back to distribution center 2, 68 kg of goods from distribution center 1 and 92 kg of goods from distribution center 3 are unloaded. In this deployment, the goods of distribution center 1 are completely distributed to the other two distribution centers and distributed by these two distribution centers.

ISSN: 2688-9323

4.3. Path Optimization Analysis

Compared with the independent distribution of each distribution entity, collaborative distribution can reduce the number of vehicles dispatched, reduce the mileage, and effectively reduce the overall distribution cost. In this example, to verify the effectiveness of the algorithm, the collaborative and non-cooperative modes use the same load and for mileage-constrained vehicles, the results are shown in Table 4. The collaborative delivery model reduces the driving cost by 31.15%, and the total cost is optimized by 20.86%, which fully proves the superiority of the collaborative delivery model.

Table 4. Analysis of optimization results

	Driving cost	Delivery cost	Charging fee	Allocation driving cost	Cost of dispatching	Total cost	Opt range
Distribution center1	184	100		0	0	284	
Distribution center2	176	150	0	0	0	326	
Distribution center3	205	150	15	0	0	370	
Total cost before change	565	400	15	0	0	980	
Total cost after change	389	300	0	37	50	776	20.84%

5. Conclusion

In this paper, based on the characteristics of electric unmanned vehicles, under the premise of considering load constraints, mileage constraints, etc., a coordinated delivery model of multiple delivery entities at the end that takes electric unmanned vehicles as vehicles and takes into account dynamic pickup needs is built. The minimum objective function of the sum of the cost of traveling, charging, and mileage in the two stages of delivery and delivery.Use Matlab software to simulate and verify the built model, and simulate and analyze the 3×20 level examples respectively, verify the effectiveness and superiority of the terminal collaborative delivery model proposed in this paper, and prove the collaborative delivery model based on this model It is practical.

References

[1] Yang Qiu, Feng Pengxiang, Sun Hao, et al. Research on site selection and route optimization of electric vehicle logistics distribution system[[J]. China Management Science, 2015, 23(9):87-9b.

[2] Shao Sai, Bi Jun, Guan Wei. Vehicle routing problem based on dynamic demand of electric vehicles[J]. Journal of Jilin University (Engineering and Technology Edition), 2017, 47(06): 1688-1695.

[3] Li Jie, Zhao Xudong, Wang Yuxia, CHU Chao-hsien. Electric vehicle configuration and path integration optimization for e-commerce terminal logistics distribution[J]. Operations Research and Management, 2018, 27(10): 23-30.

[4] Wang Yongcong. Research on urban distribution vehicle routing problem based on pure electric vehicles [D] Beijing Jiaotong University, 2016.

[5] Jie Wanchen, Yang Jun, Yang Chao. Research on branch pricing algorithm for multi-model electric vehicle routing problem[J]. System Engineering Theory and Practice, 2016, 36(7):1795-1805.

ISSN: 2688-9323

[6] Lin J, Zhou W, Wolfson O. Electric vehicle routing problem[J]. Transportation Research Procedia, 2016, 12:508-521.

[7] Goeke D, Schneider M. Routing a mixed fleet of electric and conventional vehicles[J]. European Journal of Operational Research, 2415, 245(1):81-99.

[8] Yang J, Sun H. Battery swap station location-routing problem with capacitated electric vehicles[J]. Computers&Operations Research, 201 S, 55(C):217-232.

[9] Bruglieri M, Pezzella F, Pisacane O, et al. A variable neighborhood search branching for the electric vehicle routing problem with time windows[J] .Electronic Notes in Discrete Mathematics, 2015, 47 (3):221-228.

[10] Liu Ming, Zhao Lindu. Research on the Hybrid Cooperative Distribution Mode of Emergency Materials [J]. Control and Decision, 2011, 26(01): 96-100.

[11] Li Ding, Huang Yuanxin, Tian Hongying, Li Xiaoyu. Simulation Research on Cooperative Distribution of 3PL Enterprises in Virtual Environment[J]. Logistics Technology, 2009, 28(07): 117-120.

[12] Wang Xiaobo, Li Yijun. Optimization of vehicle scheduling with time windows based on improved two-stage algorithm under e-commerce [J]. China Management Science, 2007(06): 52-59.

[13] Lee H, Padmanabhan P, Whang S. The Paralyzing Curse of the Bullwhip Effect in a Supply Chain[J]. Nederlands Tijdschrift Voor Geneeskunde, 1997, 107:2272-2275.

[14] Stanislaw Iwan, Kinga Kijewska, Justyna Lemke. Analysis of Parcel Lockers' Efficiency as the Last Mile Delivery Solution--The Results of the Research in Poland[J]. Transportation Research Procedia, 2016, 12:644-655.

[15] Linet Özdamar, Onur Demir. A hierarchical clustering and routing procedure for large scale disaster relief logistics planning[J]. Transportation Research Part E,2012,48(3).