Vehicle Routing Problem for Electric Unmanned Vehicles Considering Charging and Dynamic Demand

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Abstract

In response to dynamic demands, a route update strategy based on update time is proposed to adjust the route online in real time. And establish a charging model to allocate charging stations for routes with charging needs. Finally, an example simulation route update process is given. Take the strategy running time and the total additional cost as evaluation indicators to analyze the update time parameter. The results show that a strategy with less update time can quickly respond to demand and reduce costs. As the update time increases, the dynamic demands that need to be processed and the number of recharges increase, which leads to an increase in strategy running time and costs. The longest running time of the strategy is within the acceptable range, indicating that the strategy is feasible and practical.

Keywords

Transportation Engineering; Electric Vehicle; Vehicle Routing Problem; Dynamic Demand; Charging; Route Update Strategy.

1. Introduction

With its good environmental protection and energy adjustment effects, electric vehicles have become the mainstream technology direction that promotes vehicle energy saving and emission reduction, and realizes the technological transformation, upgrade and leapfrog development of the automotive industry. The characteristics of electric vehicles are fully in line with the objective requirements of the modern logistics industry, and are consistent with the development direction of "green logistics" [1] proposed in recent years. Under the guidance of policies and the promotion of demonstration operations, electric vehicles have made preliminary attempts in the field of logistics. Many related studies, such as the problem of electric vehicle routing, have also attracted scholars' attention.

An electric vehicle is a type of vehicle that is driven by all or part of electrical energy. However, due to battery technology issues and limited driving range, electric vehicles are incompatible with traditional gasoline vehicles in terms of vehicle routing.

with. And sometimes the mileage required to complete the trip cannot be met, so that the vehicle needs to go to the charging station to replenish the battery on the way. In recent years, domestic and foreign scholars have done little research on the vehicle routing problem based on electric vehicles. Most of the models are established by considering different influencing factors such as driving range constraints, charging constraints, load constraints or time window constraints, and finally using algorithms to solve them. Sevgi[2] is aimed at the short driving range of electric vehicles and the lack of charging facilities.

Considering the time window constraints, the green vehicle routing problem is proposed, and two heuristic algorithms are used to solve the problem in order to reach the minimum total travel distance; Schneider [3] studied the application of electric vehicles in the logistics problem "last mile", considering customer time and goods Constraints on weight and driving range, and proposed a path optimization and scheduling model for electric logistics vehicles to avoid useless routes for long-term delivery of goods, and can select appropriate charging stations for charging when the remaining mileage cannot meet the delivery task; Conrad [4] considers The mileage constraint allows the vehicle to be charged at the customer site, proposes the charging vehicle path problem, and finally predicts the average mileage; Worley [5] also combines the charging station location problem and the electric vehicle path problem to establish a model. Liu Huaxu [6] focused on the driving range constraint, charging demand and charging time, established an electric vehicle logistics distribution scheduling model, and solved it with an ant colony algorithm, and finally analyzed the rationality of each distribution plan. Gao Sheng [7] constructed an electric vehicle routing problem model with the goal of minimizing the total delivery cost.

In the above research, all the information is certain. However, in actual logistics and distribution, some information such as customer needs and traffic conditions are often uncertain. This uncertain information is likely to dynamically change the route, and we need to make timely adjustments at this time. Therefore, since the 1990s, the dynamic vehicle routing problem has attracted widespread attention and research. Psarafti [8] defines a dynamic problem as: not all information is known before the route is made, but with the initial route

The implementation is gradually obtained; and some information about the initial route will change over time. According to different dynamic characteristics, the dynamic vehicle routing problem is divided into many kinds [9]. The dynamic demand vehicle routing problem is one of the important branches. Xiong Hao [10] defines the dynamic demand vehicle routing problem as: under the conditions of modern information technology, in the process of executing the path, the information related to customer needs is continuously revealed to the decision makers over time, and the problem of real-time optimization of the vehicle routing is required . At present, there is no research on the dynamic vehicle routing problem specifically for electric vehicles. As the carrier of transportation of goods in distribution, how to fully play its role in dynamic environment and improve distribution efficiency has become the focus of this article. This article solves the problem of vehicle routing based on dynamic demand of electric vehicles by considering mileage constraints and charging requirements, plans a reasonable distribution plan and charging plan, and effectively avoids battery over-discharge due to insufficient power during driving on the basis of meeting customer needs or the vehicle broke down, etc.

2. Problem Description

The unmanned vehicle used in this article is an electric drive, which can be supplemented by charging piles in the area to obtain a longer cruising range. The charging mode is fast charging, and the charging is completed within 30min-1h. This article assumes that the charging station is fully charged without waiting. After adding dynamic demand, the original charging plan may need to be adjusted due to route changes. The new charging plan may increase the number of charging times and increase the mileage of the vehicle to the charging station to charge. This part of the newly increased driving cost And the charging fee is the extra cost of charging. The increased charging time will also affect the subsequent addition of dynamic demand, which makes the adjustment of the route more complicated. Therefore, it is also one of the goals of this phase to minimize the additional charging cost in the dynamic phase.

In summary, the problem of simultaneous delivery based on electric unmanned vehicles can be described as: electric unmanned vehicles in each distribution center first deliver to each distribution point according to the route planned in the distribution stage; The demand for pick-up is generated, so that the delivery route needs to be adjusted according to the new demand, and the charging plan needs to be re-planned to complete all the pick-up and delivery tasks. In order to simplify the problem and better focus on the problem itself, this article makes the following assumptions:

(1) Each distribution point has one and only one unmanned distribution vehicle to serve it;

(2) The unmanned vehicle starts from the distribution center to carry out the distribution operation according to the established route, and it is also necessary to transport the goods picked up by the pickup demand back to the distribution center. In the process of distribution, the addition of dynamic demand does not change the order of distribution;

(3) Considering the problem of multiple parking lots, all unmanned vehicles depart from each distribution center, and finally return to any distribution center nearby, without returning to the distribution center of departure;

(4) In order to get a quick response to the dynamic demand, the dynamic pickup information is received from the time the vehicle departs. This article updates the route according to the time interval, and the information center adds the received pickup information to each updated time point. For each delivery route, close the window for receiving pickup information a certain time before all delivery tasks are completed on the day;

(5) All unmanned distribution vehicles are fully charged when they depart from the distribution center, and can be replenished for multiple times according to demand during the mission;

(6) The locations of all charging stations in the mission area are known, and it is assumed that all unmanned vehicles arriving at the charging stations can be charged directly without waiting.

2.1 Variable and parameter definition

$C0$: Total cost

$C1$: Delivery cost

$C2$: Charging cost

$u1$: Distribution unit distance cost of distribution center (yuan/km)

$u3$: Single charge cost (yuan/h)

$f1$: The cost of a single dispatch of vehicles in 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

Nm: The collection of end demand points belonging to distribution center m

K: The collection of vehicles in the delivery stage

dij: The driving distance between point i and point j

qj: The weight of the goods at demand point j

$W\ max$: The weight of the goods at demand point j

$xijk$: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′

2.2 Distribution stage model:

$$MinC0 = C1 + C2 \tag{1}$$

$$C1 = f1 \sum_{k \in K} \sum_{i \in M'} \sum_{j \in N_m^{m'}} xijk + u1 \sum_{k \in K} \sum_{i \in M' \cup N_m^{m'}} \sum_{j \in N_m^{m'}} xijkdij \tag{2}$$

$$C2 = u3 \sum_{j \in F} yjk \tag{3}$$

$$\sum_{i \in M' \cup N_m^{m'}} xijk = 1 \quad \forall j \in N_m^{m'} \quad \forall k \in K \tag{4}$$

$$\sum_{\forall i \in M' \cup N_m^{m'}} xijk = \sum_{\forall p \in M' \cup N_m^{m'}} xjpk \quad \forall j \in N_m^{m'} \quad \forall k \in K \tag{5}$$

$$xm'jk = 1 \quad \forall j \in N_m^{m'} \bigcup m'' \quad \forall k \in K \tag{6}$$

$$xim''k = 1 \quad \forall j \in N_m^{m'} \bigcup m' \quad \forall k \in K \tag{7}$$

$$D_{jk} = [D_{ik}(1 - y_{ik}) + y_{ik}D_{\max} - D_{ij}]x_{ijk}$$
$$\forall j \in \sum_{m \in M} Nm \cup F \cup M'' \quad \forall i \in \sum_{m \in M} Nm \cup F \cup M' \quad \forall k \in K \tag{8}$$

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

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

$$\sum_{i \in M' \cup N_m^{m'}} \sum_{j \in N_m^{m'}} xijkqj \leq W\,max \quad \forall k \in K \tag{11}$$

$$yjk \leq zj \quad \forall j \in \sum_{m \in M} Nm \cup F \cup M'' \quad \forall k \in K \tag{12}$$

$$xijk = \{0、1\} \quad \forall j \in N_m^{m'} \bigcup m'' \quad i \in M' \bigcup N_m^{m'} \quad \forall k \in K \tag{13}$$

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

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.

2.3 Route update strategy

In the problem of simultaneous delivery and pick-up, in order to meet the continuously generated pick-up demand, a strategy is needed to adjust the route in real time. The currently available strategies include a proximity priority strategy, a random queue positioning center strategy, and a first come first serve strategy. The start mechanism of route update is divided into node update at the distribution point and scheduled update time. The update at the distribution node is generally used when the distance between the distribution points is relatively long. It takes a long time to complete a distribution task, and each time it is added, it takes a long time to complete a distribution task. The situation where there is a lot of demand for goods; and the mechanism of fixed update route time can set different update times according to the situation, on the one hand, respond to the demand in time, on the other hand, avoid adding too many dynamic demands at one time.

The scenario of the problem studied in this article is the end-of-city delivery, that is, the "last mile". The distance between the delivery points is relatively short, so a fixed update time is used as the starting mechanism for route update. Under the constraints of the mileage constraint and load capacity constraint of the distribution vehicle, and comprehensively consider the location of the charging station, the goal is to minimize the total additional cost of the extra charging fee caused by the change of the charging plan and the extra driving fee caused by the response to dynamic demand. Route update strategy model. Since this article does not explore the time window and customer satisfaction issues, the extra cost is used as the objective function to measure the pros and cons of the route update strategy in the dynamic pick-up phase.

The strategic process of route update is shown in Figure 1.

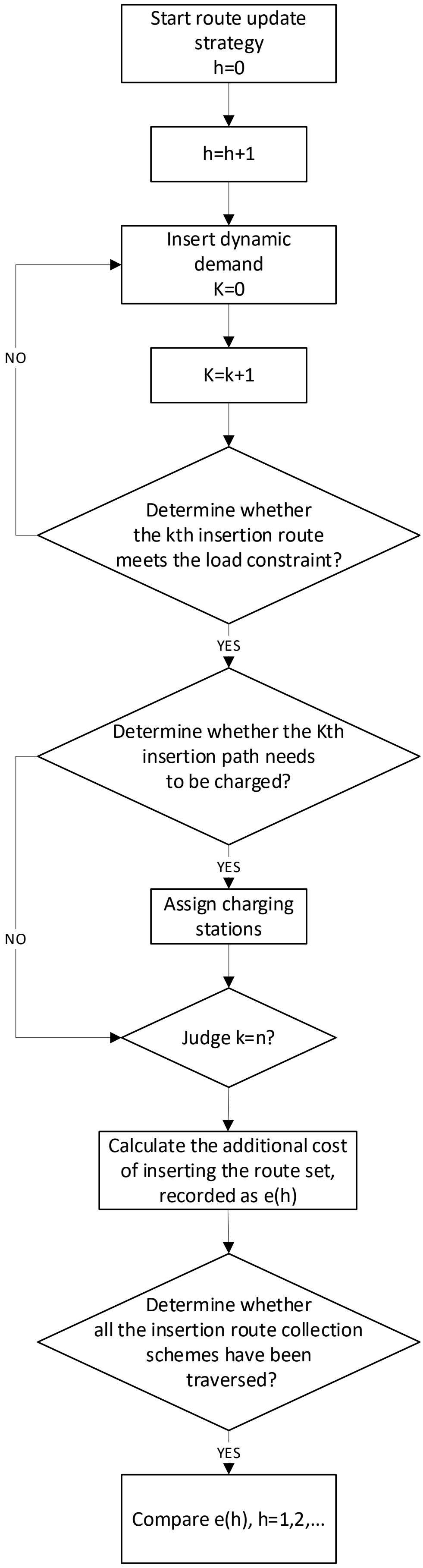

Figure 1. Flow chart of route update strategy

Step1: When the time node reaches the update cycle, start the route update strategy h=0

Step2: h=h+1. Insert all newly connected dynamic demands in this update cycle into the insertable route set in the order of arrival time to obtain a set of inserted routes. There are n routes to be selected in the set. k=1.

Step3: Select a feasible solution from the solution set, that is, select a path that satisfies the constraints. Judge whether the kth insertion path meets the load constraint, if it does not meet the load constraint, return to step 2, if it meets, then go to the next step, k=k+1.

Step4: Assign charging stations to paths with charging requirements. According to the mileage constraint, judge whether the kth insertion path needs to be charged. If charging is required, a charging model is established to allocate charging stations for the plug-in route.

Step5: Judge k=n? If yes, go to the next step, if not, go back to step 3.

Step6: Calculate the extra cost of inserting all feasible route sets and record it as e(h).

Step7: Determine whether all the inserted route collection schemes have been traversed, if yes, go to the next step; if not, repeat steps 2~6.

Step8: Compare z(h) (h=1,2...), find the minimum value of z(h), and output the corresponding inserted route plan as the new driving plan after route update.

2.4 Steps to insert dynamic requirements

The generated dynamic demand has two key points for decision making, 1) the arrival time of the dynamic demand; 2) the location of the dynamic demand and the quality of the goods.

2.4.1 Arrival time

In queuing theory, when describing a process that occurs randomly at a certain time within a certain time, because the probability distribution of events described by Poisson flow is relatively simple, and it is easy to give the characteristics of the described system in the form of functions, such systems usually adopt Poisson The flow is described. Then the time interval t for the arrival of the dynamic pick-up demand follows a negative exponential distribution, and the description function of the distribution is:

$$F(t)\begin{cases}1-e^{-\lambda t} & t\geq 0\\ 0 & t<0\end{cases}$$

λ is the arrival rate, which means the average number of dynamic demand points generated in a unit time (h).

2.4.2 Geographical location and pickup volume

The geographic location of the dynamic demand point is uniformly and randomly generated in the road network, and is mainly used to simulate the scattered demand of the goods; the dynamic demand can also be entered in advance to adjust the route of the coordinate point of the demand point and the quantity of the goods.

In the route update strategy, Step2 is to add the dynamic pickup demand to the route, and then output a set plan for inserting the route. An example is shown in Figure 2. Figure 2 (1) shows the initial route, which shows the remaining delivery route when the route needs to be updated. It can be seen that there are two unmanned vehicles performing delivery tasks outside, respectively delivering to the No. 3 and No. 4 distribution points, and the remaining mileage is called the unfinished route. There are k-2 unmanned vehicles in all distribution centers that have not been assigned tasks. These vehicles can be regarded as k-2 virtual paths that have not visited any demand point. The unfinished path and the virtual path together form a pluggable set. Due to the addition of the dynamic pickup demand, the driving path changes. Visiting the pickup point will cause the itinerary offset and the mileage increase, which will cause the original charging plan to no longer be used. Therefore, when inserting the dynamic pickup demand in the unfinished route, there is no need to consider the mileage constraint, that is, the previously allocated charging plan is removed. After completing the dynamic demand insertion, re-allocate charging stations for routes with charging demand. Any two adjacent delivery points in the set can be used as insertion points. The insertion point is when the dynamic demand is accessed. It can be seen from Figure 2(2) that when the first dynamic demand is inserted, there are 7 insertion points for the unfinished route and k-2 virtual routes, that is, a total of m+5 insertion points. Dynamic demand points are also regarded as nodes. With the insertion of dynamic demand points, the number of insertable points increases. When inserting the i-th dynamic demand, there are a total of m+i+4 insertable points. Suppose there are p dynamic demands, Can get $\prod_{i=1}^{p} m+i+4$ insert route collection schemes. Choose a solution from a collection of multiple insertion routes that have never been traversed. Figure 2(3) is one of them (p=2)

DC1→3→5→7→9→DC2

DC2→4→6→8→Recharge→10→DC1

(1) Delivery route (the route update strategy in the previous stage)

Unfinished path: 5→7→9→DC2
4→6→8→10→DC1

Virtual path: K-2 { DC→DC
DC→DC

(2) Insertable route collection

5→7→9→11→DC2

4→6→8→12→10→DC1

(3) A to-be-selected distribution route plan

Figure 2. Schematic diagram of inserting dynamic demand

2.5 Allocate charging stations

After inserting the dynamic demand, a to-be-selected distribution route plan is generated. It is necessary to check whether each distribution route in the to-be-selected distribution route plan meets the load constraint. If the load constraint is met, continue to check whether the mileage constraint is met. If the delivery route does not meet the mileage constraint, the vehicle that executes the delivery route needs to go to the charging station to recharge the battery during the rest of the trip. The charging plan update is mainly to provide the optimal charging plan for the route that has demand after the route adjustment, and mainly solves the two problems of when to charge and where to charge.

The charging plan update is the process of reallocating charging stations for unmanned vehicles that meet the load constraints but the remaining vehicle mileage is not enough to complete the remaining pickup and delivery tasks after the route is changed. The minimum additional cost model established in this paper is to minimize the additional costs incurred by allocating charging stations. Because the model is relatively simple, the branch and bound algorithm in the precise algorithm is used to solve the problem.

$$MinE = E1 + E2 \tag{15}$$

$$E1 = u1\Big(\sum_{i=1,2,\ldots,\ l-1} driri + 1 - \sum_{i=1,2,\ldots,\ n-1} dr_i{}^0 r_{i+1}{}^0\Big) \tag{16}$$

$$E2 = u3\Big(\sum_{i=1,2,\ldots,\ l}\ \sum_{j\in F} yrij\Big)_{\text{-}C}3 \tag{17}$$

$$yrij \le zj \quad i = 1,2\ldots,\ l,\ \forall j \in F \tag{18}$$

$$Dri+1=[Dri(1-yrij)+yrijD\,max-driri+1],\ i=1,2,\dots,\ l-1 \tag{19}$$

$$Dri\geq 0, i=1,2,\dots,\ l \tag{20}$$

$$yrij=\{0,1\}, i=1,2,\dots l, \forall j\in F \tag{21}$$

Equation (15) expresses that the total additional cost is composed of two parts: additional driving cost and increased charging cost; Equation (16) expresses the additional driving cost; Equation (17) expresses the increased charging cost; Equation (18) guarantees delivery Vehicles can only replenish power at the charging station; formulas (19) and (20) ensure that the remaining mileage of the delivery vehicle at any node is greater than 0; formula (21) represents the new charging plan, which is a variable of 0-1, when the node r_i is 1 for the charging station, otherwise it is 0.

2.6 Route update process output

At this stage, because there are few insertion points, it is not an NP hard problem, so an exhaustive traversal method (the scheme of traversing all the insertion routes set) is adopted to obtain multiple feasible solutions. With the goal of minimizing additional costs, compare all feasible solutions and select the optimal set of insertion routes. Before the next route update arrives, deliver and pick up the goods according to the current optimal route.

3. Simulation Analysis

3.1 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 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.

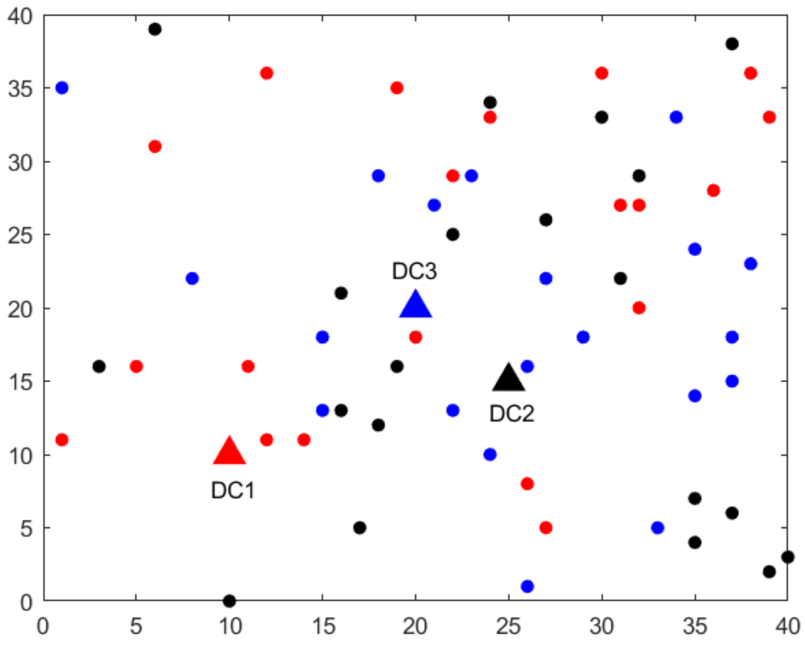

Figure 3. Coordinate map of distribution center and distribution point

There are a total of 30 charging stations in the urban area. The locations of the charging stations are shown in Figure 4. 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;

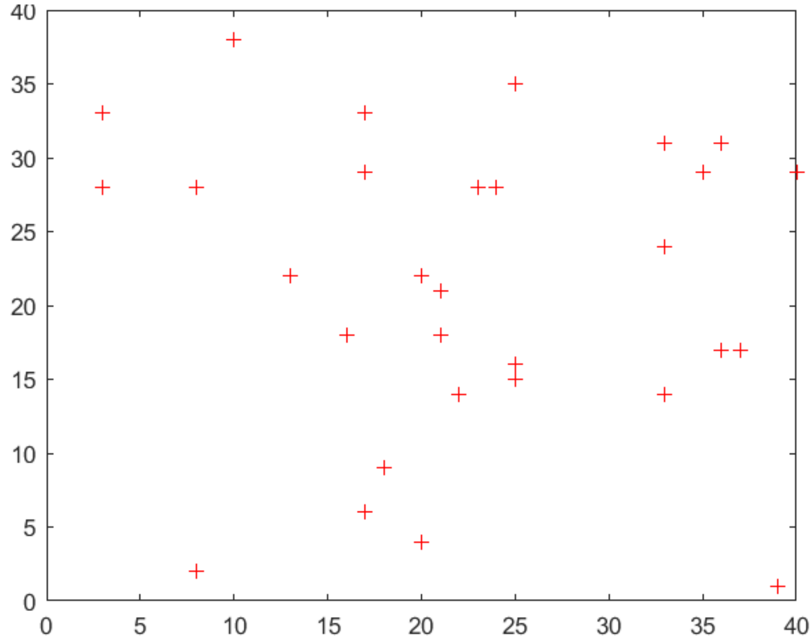

Figure 4. Location of charging pile

The route update time is set to 1h, and the arrival coefficient λ is set to 5. This simulation has set 3 route updates. The dynamic demand point positions in each time period are shown in Figure 5.

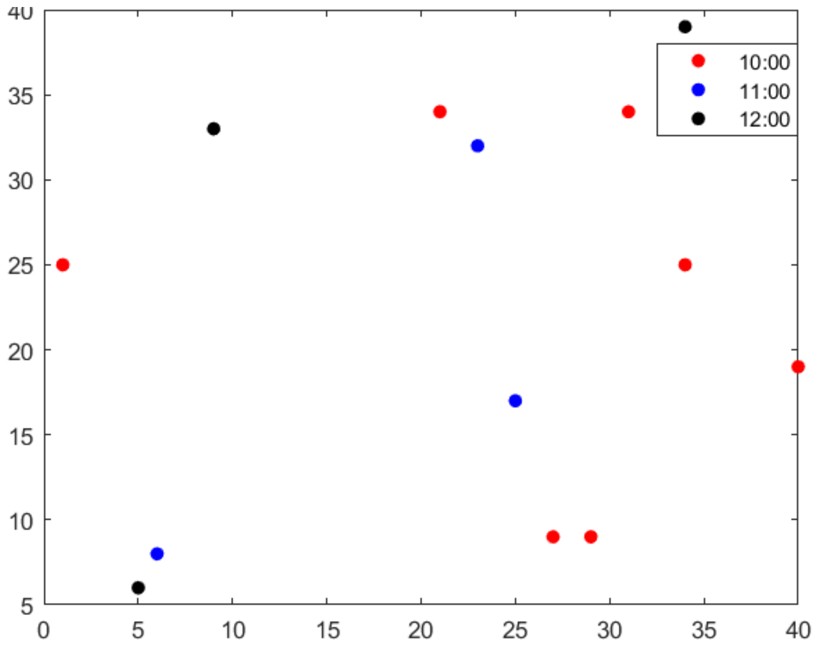

Figure 5. Insertion point coordinates

3.2 Simulation experiment analysis

With the addition of dynamic pickup demand, the route update strategy is initiated to adjust the route, and the insertion route is optimized with the goal of minimum additional cost and charging stations are allocated. In this example, time is the dynamic adjustment starting mechanism, the time is set to 60min (that is, it starts every 60min), and the path is updated three times. The Poisson event flow is used to simulate the arrival of dynamic pickup demand and the amount of pickup. Randomly generated and simulated under this condition.

The results are shown in Table 1.

Table 1. Route update table

Update time	vehicle	Adjusted route	Additional cost
10:00	1	45→42→100→8→7→63→29→44→15→1	54yuan
	2	9→96→23→62→4→19→22→recharge sit12→25→97→34→27→3	
	3	37→10→51→17→20→14→1	
	4	11→94→58→41→54→35→31→57→1	
	5	12→36→18→47→50→28→16→61→2	
	6	60→53→52→59→13→6→99→95→38→3	
11:00	1	8→7→63→29→44→15→101→1	22yuan
	2	4→19→22→recharge sit12→25→97→34→27→102→3	
	3	17→20→14→1	
	4	54→35→31→57→1	
	5	47→50→28→103→16→61→2	
	6	13→6→99→95→38→3	
12:00	1	63→29→105→44→15→recharge sit5→101→1	69yuan
	2	25→97→34→27→102→3	
	3	1(distribution center)	
	4	31→57→104→1	
	5	28→106→103→16→61→2	
	6	99→95→38→3	
13:00	1	44→15→recharge sit5→101→1	none
	2	27→102→3	
	3	1(distribution center)	
	4	104→1	
	5	103→16→61→2	
	6	3(distribution center)	

At 10:00, the first route update is performed. This time there are 6 pickup requests (No. 94~100). At this time, 6 unmanned vehicles are performing delivery tasks, and the dynamic requirements are inserted into 1, 2 and 2, respectively. 4. The additional cost incurred in the route of four unmanned vehicles is 54 yuan. For No. 2 car, after inserting the two dynamic pickup requirements of 96 and 97, the remaining mileage of the vehicle is not enough to complete the entire itinerary. Therefore, the No. 2 car is arranged to go to the nearest No. 12 to charge after completing the delivery task at the No. 22 distribution point. The pile carries on the electricity supplement. There is no change in the charging plan for the remaining routes.

At 11:00, the second route update is performed. This time there are 3 pickup requests (No. 101~103). At this time, 6 vehicles are performing the delivery task, and the dynamic requirements are inserted into 1, 2, and 5 respectively. In the path of the three unmanned vehicles, the additional cost incurred is 22 yuan. This time the demand for pick-up is relatively small, so although the route has changed slightly, each route still meets the mileage constraint, so there is no adjustment of the charging plan.

At 12:00, the third route update is performed. This time there are 3 pickup requests (No. 104~106). At this time, the No. 3 car has returned to the No. 1 distribution center, and a total of 5 cars are performing the delivery task. The pickup demand is inserted into the routes of cars 1, 4, and 5, and the extra cost incurred is 69 yuan. Among them, the remaining mileage of car No. 1 is not enough to complete the entire journey after the newly inserted pickup demand, so after completing the delivery task to the No. 15 distribution point, it will go to the No. 5 charging pile for charging. The remaining paths are not adjusted.

At 13:00, the No. 3 and No. 6 delivery vehicles have completed all the tasks and returned to the distribution center. The remaining 4 vehicles will also return to the distribution center after completing the remaining delivery and pickup tasks to wait for the tasks in the next time period. Because the charge for a single charge is 15 yuan, and the cost of a car is 50 yuan, the system tends to increase the number of charges and reduce the number of cars on the premise of meeting the load constraint.

4. Conclusion

This article first considers reservation customer demand, charging, mileage constraints and load constraints to establish the basic vehicle routing problem, and uses genetic algorithm to solve the model to get the initial route. Then propose a route update strategy based on the update time to adjust the route in real time to meet the continuously generated dynamic demand, and establish a charging model to allocate charging stations to the route with charging demand to avoid battery over-discharge or vehicle breakdown due to insufficient power Wait for the situation. Finally, an example simulation route update process is composed of 3 distribution centers, 60 reservation customers, 3 random dynamic demands and 30 charging stations. As dynamic demands are inserted, routes and charging plans are constantly changing. However, due to the high cost of re-dispatching vehicles, the route update strategy preferentially selects a single charge inserted into the route. It is proved that this algorithm can effectively respond to the demand for picking up goods during the delivery of electric unmanned vehicles.

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