Study on Site Selection and Network Optimization of Charging Pile of New Energy Logistics Vehicle

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Abstract: New energy logistics vehicles have become the general trend of urban distribution development. However, in the actual operation and self-development process of domestic new energy logistics vehicles, there have been many new problems, such as the matching degree of the number of new energy logistics vehicles and charging piles is not high, and some regions can not meet the needs of vehicle charging. Therefore, it is of great significance to study the rationalization of charging facility layout and vehicle distribution path planning. After combing and summarizing the existing literature on the layout of charging facilities and vehicle distribution path planning at home and abroad, this paper proposes to consider the location of charging pile and the optimization of distribution path.

Key words: New energy logistics vehicle; Charging facilities; Path optimization; The layout planning

1. The introduction

In recent years, with the increasingly prominent problems of resource shortage and environmental pollution, it is urgent to promote the application of new energy logistics vehicles and the planning and construction of public charging facilities in China. Therefore, the research on the layout of charging facilities and vehicle distribution path planning has strong practical significance.

Based on the literature survey on the location of charging pile and charging site and the optimization of distribution path of new energy electric vehicles, most scholars only study the location of charging pile and charging distribution path optimization of new energy logistics vehicles separately, and divide it into two independent research contents. In real life, the two are interrelated. The location of charging pile affects the optimization of distribution path of new energy logistics vehicle.

A few scholars study the correlation between the two to calculate the optimal solution of the charging pile station. In the literature available at present, the factors involved in the establishment of objective function are similar, and the constraints are basically similar.

After consulting the literature and based on the existing research in the literature, this paper establishes an appropriate model, fully considering the vehicle charging cost, environmental pollution cost, facility construction cost, logistics transportation (manual labor) cost, mileage, maximum load capacity, vehicle power constraints, vehicle charging cost and environmental pollution cost, so as to balance the economic, environmental and social performance.

2. Model building

2.1 Construction of initial site selection model

(1) Problem analysis

Distribution vehicle need to spend a lot of time to express Courier site handling activities, while the distribution vehicle can only wait for the loading and unloading homework finished, the empty window period for new energy vehicle logistics provides a convenient, fast charging activities can effectively improve the working efficiency of the distribution vehicle, therefore, it is necessary in dc fast charging pile, express site construction In order to achieve the maximization of business interests. The project selected dc quick charging piles with advantages such as flexible assembly and small footprint as the charging equipment of express stations to design. Due to the requirements of the enterprise to balance funds, the project selected some core express stations in the distribution network to construct DC quick charging piles.

(2) Model building

The set coverage problem is to establish the minimum number of facilities to meet the needs of all customer points. In the model to be established in this problem, the minimum number of facilities location points is used to cover all customer demand points.Based on the assumption that all express delivery stations are reasonable, in the initial site selection, we take all express delivery stations as candidate points, investigate all candidate points, and construct sufficient number of

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charging piles that can cover all customer demand points with the lowest cost. Therefore, the preliminary selection point model is constructed as follows:

$$\min E = \sum_{l \in L} P_l \alpha_c \quad \text{Formula 1}$$

$$\text{s.t.} \begin{cases} \alpha_c \in \{0, 1\} & \text{Formula 2} \\ \sum_{l \in L} a_c \geq f_{cl} \ (c = 1, 2, \ldots C;\ l = 1, 2, \ldots L) & \text{Formula 3} \\ \forall l \in L, \forall c \in C, L \in C & \text{Formula 4} \end{cases}$$

Formula 1 is the objective function, and Formula 2, 3 and 4 are constraint conditions, that is, the minimum value of the objective function is guaranteed under three conditions. Formula 1 represents the total cost of charging facility construction. In the initial site selection, we should ensure that the total cost E reaches the minimum value to ensure that the cost is controllable. Formula 2 represents the value range of decision variable c , that is, if the charging pile is constructed at point C, AC is 1; otherwise, ac is 0.Formula 3 represents that each customer demand point is covered by at least one quick charging facility, that is, to ensure that each customer demand can be met; Formula 4 restricts the selection of all charging pile sites to be guided by required sites, and charging piles are built at sites with customer requirements.

(3) Algorithm design

This model can be classified as a radius coverage problem, which is solved by greedy algorithm. The number of facility site selection and optimal objective function value are initialized, and the number of customer demand points in the circle drawn by each candidate location point as the center of the circle is recorded. This value represents the number of possible service to express stations of each candidate charging station. All candidate facility location points are arranged in descending order according to the number of covering demand points. On the premise that the candidate facility location points can cover all demand points, the first N candidate facility location points are selected as the initial sites, and N is the minimum number of charging facilities that can meet the needs of all customers.

2.2 The Model building of NVLRP

NVLRP (New Energy Logistics Vehicle Location and Routing Problem), namely, New energy logistics Vehicle charging facility layout planning and distribution path optimization.

(1) The problem analysis of NVLRP model

At present, there are two urgent problems for enterprises to solve: on the one hand, how to realize the conversion of logistics vehicles with the lowest cost; On the other hand, in the current charging facilities are not perfect, how to solve the problem of vehicle charging. In view of the two main problems, two research objectives are proposed: one is to provide decision-making for the site selection of the construction of quick charging piles in logistics enterprises; The second is to plan the optimal distribution path for new energy logistics vehicles. After consulting materials and investigating practical problems, the elements of the distribution path optimization model of new energy electric vehicles and its relational structure are shown in Figure1:

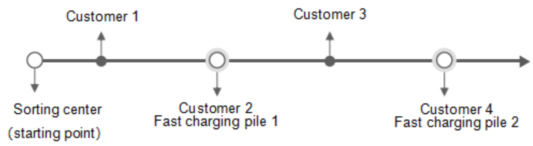

Fig. 1 One-way distribution route of new energy logistics vehicle

Description of model elements:

new energy logistics vehicles -- assuming that the model only involves a typical type of new energy logistics vehicles, so the load, range, charging power, charging socket, maximum storage is unique.

Sorting center -- the starting point of logistics transportation, to ensure that the battery power of logistics vehicles in non-working hours to maintain adequate state.

Customer -- the downstream of logistics transportation, plays an important role in the process of charging facility location and distribution route optimization.

Quick charging pile -- with construction cost, charging power, location information and other characteristics.

(2) The Preliminary construction of new energy electric vehicle distribution path optimization model

Through the analysis of the problem, a single objective programming model is established. The objective function of single objective programming is the total cost of all aspects, and the purpose is to minimize the total cost. The objective function and constraint conditions are shown below.

①The objective function

The objective function applied in single objective programming and multi-objective programming has different construction forms but the same composition. The team integrated the elements and their properties of the model and calculated the costs of all aspects, including the construction cost of quick charging pile X1, charging cost X2, and manual labor cost X3, which were respectively expressed by the following formula.

P_l is the construction cost of a single quick charging pile, α_c is the decision variable, whether to build at point c: $X_1 = \sum_{l \in L} p_l \alpha_c$; $\beta_{l,n}$ is the decision variable, indicating whether the vehicle n is charged at the station 1, Δt is the charging time, which can be accurately expressed by the electric difference between departure and entry of the new energy logistics vehicle and charging power: $X_2 = \sum_{n=1}^{N} \sum_{t=t_{l,n}}^{t_{l,n}+\Delta t} p1(t) * \Delta t * \beta_{l,n}$ and $\Delta t = (U - U1)/h$; Determine labor cost according to unit mileage, then get the total labor cost: $X_3 = p_0 \sum_{n=1}^{N} \sum_{i=1}^{C} \sum_{j=1}^{C} nD_{ij}$; To sum up, the overall objective function is: $\min X = X_1 + X_2 + X_3$.

②The constraint

The constraint conditions mainly include two constraints of the new energy logistics vehicle itself, namely vehicle path constraint and loading constraint. Combined with the actual logistics distribution process, the relationship between logistics vehicles and distribution stations is one-to-many relationship. $\sum_{n=1}\sum_{l\in L}\delta_{lc}$, $n=1$ and $\sum_{l\in L}\delta_{lc},(n\le 1, a=1,2,\ldots\ldots,N)$;The vehicle has rated load capacity. For each delivery process, the total demand for goods at all express stations passing by is less than the load capacity of new energy logistics vehicles, then: $0\le V_D\le V$,$V_D=\sum_{c=1}^{C}V_c, c\in C$.

(3) Algorithm design

Based on a large number of customer points, there are a large number of feasible construction points. Using the heuristic algorithm to solve the problem, a wider range of possibilities will be taken into account and a more appropriate solution will be obtained.

The concrete realization is the combination solution of location and path simultaneously. In order to avoid falling into the vicious circle of local optimal solution, genetic algorithm is used to generate the initial solution set, and then tabu search is used to obtain the optimal solution of both location and path problem. The specific process is shown in Figure 2.

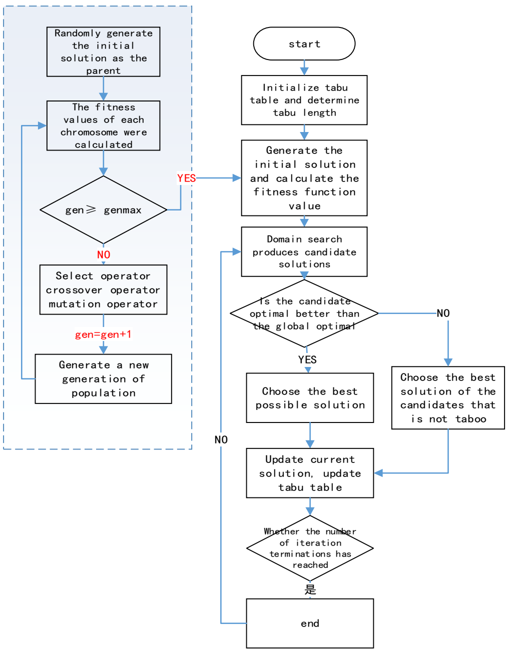

Fig. 2 Flowchart of genetic algorithm optimization tabu search algorithm

3. Case overview and basic data

3.1 Case situation

Taking a new energy logistics company in Qingdao as a case study, this paper solves the logistics vehicle cargo distribution scheme optimized by NVLRP model, compares it with the fuel vehicle distribution scheme, and calculates the cost of the two distribution services.

The existing logistics distribution process of new energy logistics companies has the following problems:

In order to ensure that logistics vehicles can return to the sorting center smoothly after completing the distribution service, the performance of vehicle mileage in the distribution service is considered as the main factor.

Currently, Qingdao is not equipped with perfect charging equipment. Most public charging piles cannot provide charging services for new energy logistics vehicles, which is easy to cause drivers to have range anxiety.

Enterprises need to equip new energy logistics vehicles with charging piles in addition to the sorting center, to ensure that vehicles can be charged in time during the distribution process, and maximize resource utilization.

The company's distribution vehicles are all EM30 new energy logistics vehicles. Dongfeng Ratate EM30 has a range of 200km and has two charging modes of fast charge and slow charge. The battery can be fully charged after 13 hours of slow charge. Fast charging takes just 2.5 hours to reach 80% of the battery's capacity.

3.2 Charging facility layout and distribution route optimization results of a company in Qingdao

(1) Solution of initial location of charging facilities

Number the delivery stations and candidate sites for building charging piles.Extract the distance between the sorting center and the express delivery station, and stipulate that at least one charging pile can meet the charging demand.Logistics car range covers round radius is one over ten of the picture, because the Courier the distance between the site known, in this paper, with the aid of EXCEL screen at a distance of less than 20 data represent points covered demand, instead of the circle is to cover the steps, for each delivery site after establishing charging stations to cover other charging demand is much more straightforward.

By using Python to solve the greedy algorithm, the candidate sites for the initial site selection of charging facilities of a new energy logistics company in Qingdao are numbered (2,4,12,13,27,29).

(2) Model solving of NEVLAP

The encoding method of the site is represented by a natural number, and the encoding sequence is the sequence of the site C={C1, C2, C3...C29}.Algorithm search operator selection of insertion operator: for a distribution path, assuming that y points with charging piles are found, a charging station is deleted from this distribution path and randomly inserted into any distribution path to generate new multiple paths.The optimal solution is selected as the current solution of the next iteration.Output results until the end of iteration.

(3) Solution results

According to the running results, the optimal solution of NVLRP model is 5284.14 yuan, and the specific data is shown in Table1.

Table 1 Optimal solution of NVLRP model

Optimal solution (yuan)	Construction costs (yuan)	Charge the cost (yuan)
2041.584	40.854	986.251
Environmental costs(yuan)	Artificial cost(yuan)	Solution time(s)
204.683	809.796	22.5814

The objective function of the model is the total cost of logistics distribution of a new energy logistics company in Qingdao.

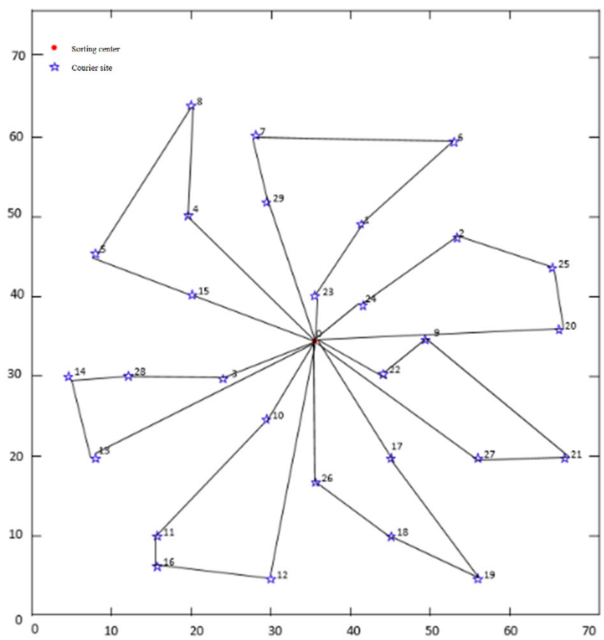

Fig. 3 Distribution path of vehicles with charging piles

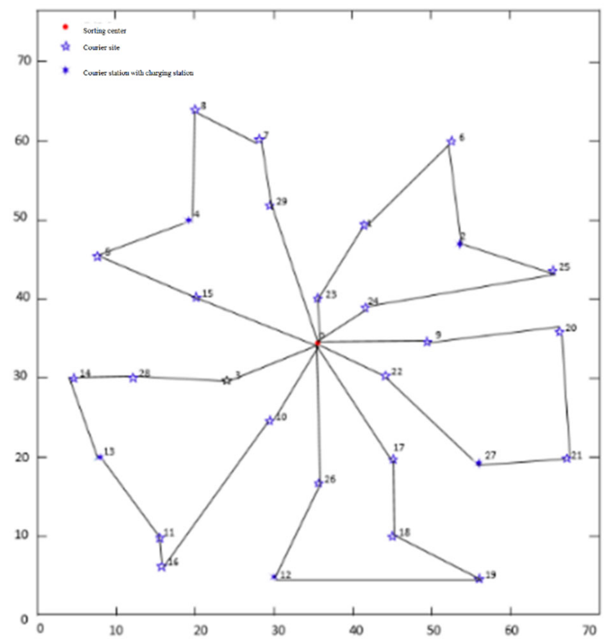

Fig. 4 Distribution path of vehicles without charging piles

The results show that in the logistics distribution scheme of the company, a total of 5 new energy logistics vehicles are needed for distribution operations, 5 of them are charged at one of the express stations in the distribution path to ensure the normal progress of logistics activities. The optimal distribution path is shown in figure 3、table 1. The vehicles replenish electric quantity at express stations numbered (2,4,12,13,27) respectively.

Table 2 Optimal distribution route

vehicle	Building the optimal distribution path of charging pile	The optimal distribution path of charging pile is not built
1	0-23-4-6-2(charging) -25-24-0	0-23-1-6-7-29-0
2	0-9-20-21-27(charging) -22-0	0-24-2-25-20-0
3	0-10-16-11-13(charging) -14-28-3-0	0-22-9-21-27-0
4	0-17-18-19-12(charging) -26-0	0-17-19-18-26-0
5	0-29-7-8-4(charging) -5-15-0	0-12-16-11-10-0
6		0-13-14-28-3-0
7		0-15-5-8-4-0

3.3 Analysis of charging facility construction strategy

The sensitivity of LRP model is analyzed. The optimal solution of logistics distribution cost of building charging pile is compared with that of not building charging pile. The comparison results show that the distribution cost of enterprises after establishing charging pile is lower, which saves 1251.624 yuan per day and 2 new energy logistics vehicles than that without charging pile. From the perspective of minimizing the distribution cost of enterprises, enterprises should choose to establish charging piles. The vehicle distribution route when a new energy logistics company in Qingdao does not build charging piles is shown in Figure 4.

4. Papper summary

Based on the research in this paper, the following conclusions are drawn.
the initial site selection of charging piles is carried out in this paper, and then the layout planning of charging facilities and vehicle path planning are studied on the basis of the candidate charging facility points obtained from the initial site selection.
The NVLRP model established in this paper takes the minimum distribution cost of logistics enterprises as the objective function and takes into account the construction cost of charging facilities, charging cost, labor cost and environmental cost. In terms of constraints, distribution

vehicle constraints, route constraints and vehicle load constraints are taken into account.

This paper takes a new energy logistics company in Qingdao as a case for analysis and research, and solves the route optimization of logistics vehicle distribution and the location and positioning of charging pile. Compared with the distribution scheme without the construction of charging piles, it is concluded that the construction of charging piles is an effective strategy to reduce the cost of enterprises.

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