Based on Particle Group Algorithm of Route Planning for Transportable Charging Station

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Abstract. Aiming at the problem of path planning for transportable charging stations, a site selection model and path planning model for dedicated routes for transportable charging stations are proposed. The path planning problem model includes the vehicle path problem and the dynamic path problem, and the path planning model is emphatically studied. Considering the network optimization model of chargers and transportable charging station paths, by establishing a path planning model, setting parameters and models, using particle swarm algorithm to calculate the path planning model of chargers and mobile charging stations (Vehicle Routing Problem Considering Stationary and Movable Charging Points (referred to as "VRP-SMCP") is solved, and the feasibility and effectiveness of the proposed model and algorithm is verified through comparative analysis of calculation examples, and the optimal path planning under the condition of minimizing cost is obtained.

Keywords. Transportable charging stations; path planning; particle swarm optimization.

1. Introduction
At present, the transportable charging stations for electric vehicles are still in the initial stage, and the problem of charging difficulty has become the main factor restricting the development of electric vehicles, but the benefits of transportable charging stations cannot be ignored, which can not only bring economic benefits, but also bring certain social value. Transportable charging stations is a mobile charging equipment derived from the objective conditions that do not allow the installation of fixed charging piles and the absence of fixed parking Spaces. It has the advantages of transportable and sharing, which solves the problem that consumers cannot charge. References [1-2] expounded the development status and future development trend of electric vehicles at home and abroad; Reference [3] presented the development status of charging piles, and put forward practical countermeasures and suggestions such as value-added services and coordination norms for practical problems such as profit mode of portable charging stations and industry standards; References [4-6] researched and analyzed the problems facing the large-scale application of charging piles in China and puts forward the corresponding countermeasures; References [7-9] analyzed the current situation of electric vehicle charging stations in Beijing, and it also analyzed the problems of charging stations and put forward some policies, planning and design suggestions, which optimized the layout of portable charging stations; References [10-11] proposed an optimal model for charging station planning and layout with minimum cost; Reference [12] introduced the basic principle of particle group algorithm, and studied
the optimization planning of charging facilities on this basis; References [13-14] put forward the application scope of the charging station construction mode and its planning and construction ideas; References [15-17] studied the problem of urban transport path which based on pure electric vehicles, and it analyzed the feasibility and necessity of its application to urban transport.

Compared with the traditional vehicle planning problem, foreign experts have made a lot of exploration. Yang [18] and others considered the limited site selection of charging stations and vehicle path planning, but the vehicle path planning to pure electric vehicle transportation research, the main focus of charging stations, vehicle path and so on.

2. Current Status of Charging Piles and Transportable Charging Stations

2.1. Current Status of Fixed Charging Pile
Under the background of the government vigorously promoting electric vehicles, the traditional automobile enterprises have begun to strategically plan the development of electric vehicles, and some high-tech companies are also rapidly entering the market. According to incomplete statistics from 2010 to 2016, China had built and operated fixed charging piles of 141,000, which doubled from the previous year, and China ranked the largest number of charging piles and transportable charging stations in the world. The number of electric vehicles increases year by year, but the difficulty in charging has become the main factor restricting the development of electric vehicles. The operation mode is not mature and the profit mode is relatively vague; the policy tendency is unknown, the enterprise operation risk is still there; the charging pile is later developed, and the technology is relatively backward.

Therefore, there are still some technical problems, and the development of transportable charging station depends on multiple support, and the coordination is difficult.

2.2. Development Status of Transportable Charging Station Equipment
At present, the research and development of transportable charging equipment at home and abroad is still in a period of development, and which is not fully mature in technology and operation mode. Put transportable charging vehicles in areas where some objective conditions are not allowed or fixed charging pile maintenance. This "Fixed + Removable" charging service can meet the daily charging needs of pure electric vehicles and solve the problem of difficult charging in a state of emergency.

Charging through portable charging stations, it has obvious advantages in improving the utilization rate of vehicles, getting rid of site restrictions, and it is popular with the market. It solves the key problems of short range, long charging time and high charging station construction cost of traditional new energy vehicles, and it will effectively solve the problem of inconvenient charging of electric vehicles in the field of public services.

This paper presents a review of portable charging stations (figure 1). Removable charging station includes pile main control module, cabinet main control module and electrical property module. The cable preinstallation technology of charging terminal and rectifier system is adopted.

![Figure 1. Transportable charging station.](image-url)
3. Optimization Model of Bus Special Route Network

3.1. The Model of the Path Problem

From the definition of Vehicle Routing Problem (VRP), the components mainly include bus terminal, Vehicle, customer, transportation network constraints and objective function. Based on these components, VRP problems can be classified into different types. According to the condition of the man, it can be divided into full load problem, load constraint problem, full load and unsatisfied mixed problem, etc. From the objective function, it can be divided into dynamic demand problem, static demand problem, single objective problem and multi-objective problem. The mathematical model is as follows.

\[
\min z = \sum_{i=0}^{0} \sum_{j=0}^{0} \sum_{m=1}^{0} c_{ijm} x_{ijm} 
\]

\[
\sum_{i=0}^{K} d_{ijm} y_{m} \leq Q, m = 1, 2, \ldots, M
\]

\[
\sum_{m=1}^{M} y_{i} = 1, i = 1, 2, \ldots, n
\]

\[
\sum_{i=1}^{n} x_{ijm} = y_{m}, j = 1, 2, \ldots, n; m = 1, 2, \ldots, M
\]

\[
\sum_{j=1}^{n} x_{ijm} = y_{m}, i = 1, 2, \ldots, n; m = 1, 2, \ldots, M
\]

Equation (1) indicates that the optimization goal is to minimize the total distance of vehicle transportation; Equation (2) is vehicle-mounted constraint, indicating that the total demand of all customers on each line does not exceed the vehicle-mounted limit of a single transport vehicle; Equation (3) indicates that every passenger is served and the number of service is only once; Equations (4), (5) indicate the access balance of vehicles at passengers. The specific form path of an electric vehicle when performing the task is shown in table 1, where 0 means the bus terminal, the digital means the node, the node with parentheses is a fixed charging pile, and the node with parentheses indicates the mobile charging station.

| Vehicle number | Vehicle driving path          |
|----------------|-------------------------------|
| 1              | 0-19-{20}-15-0               |
| 2              | 0-23-[17]-16-7-26-0          |
| 3              | 0-6-11-{10}-9-0              |
| 4              | 0-5-[25]-1-0                |

In fact, the vehicle routing problem is more complex, and the same problem has multiple components, such as load-constrained vehicle routing problem, dynamic vehicle routing problem, etc. For this problem, particle swarm optimization algorithm is adopted in this paper to solve. From the result of route optimization, it is found that when the vehicle runs for a long distance, it must enter the public charging service facilities for quick charging on the way, otherwise it cannot return to the bus terminal. Moreover, in the simulation city setting, the number of transportable charging stations is fewer than that of fixed charging piles.
3.2. The Model of Bus Station Center Location Problem

The location of bus centers refers to the number of centers and coordinate coordinates within a few sub-bus stations and a certain economic area. The solution of this problem not only addresses the location selection of enterprises and schools, but also partly determines the operating cost and response speed of the bus terminal. The investment cost of such large construction facilities is large, and it is generally difficult to change after completion, which also highlights the importance of the site selection of bus stations.

The site selection problem of transportation center is similar to other bus transportation problems, which is to minimize cost minimizing, so the target function of the model established in this paper is also cost minimizing. In the actual site selection problem, the passenger traffic rate, the surrounding human flow density and the distance of the demand points should be considered. To simplify the calculation, the target function of transport passenger center is established.

The objective function (6) in the model represents cost minimization, where the first item represents the total transportation cost from the bus terminal to the bus terminal, the second item represents the fixed cost of building the bus terminal, and the third item represents the storage cost of the bus terminal. Due to the differences in various places within the region, the cost of bus stations established in different areas is different. When calculating the total cost, it is assumed that the demand for pedestrian flow is continuous and uniform.

4. Design of VRP-SMCP Model Algorithm Based on Particle Group Algorithm

4.1. Principle of the Particle Group Algorithm

In the particle group algorithm, the potential solution to each optimization problem can be imagined as a bird in the search space, called a particle. All particles have an adaptive value determined by the optimized function, and each particle also has a velocity that determines the direction and distance of its movement. The particle position is updated as shown in figure 2.

In figure 2, X represents the initial position of the particle, V represents the moving speed of the particle, and p represents the optimal position searched to the particle. The speed update formula consists of three parts: inertial, cognitive and social parts. The first part reflects the tendency of particles to maintain their previous speed; the second part reflects the trend of the particles, and the group history experience of particle group collaboration and knowledge sharing, representing the trend towards the best position of group history. Therefore, the particle group algorithm has a great advantage in solving the multi-objective optimization problem.

4.2. Characteristic Analysis of the VRP-SMCP Model

This paper designs a path planning model considering the charging pile and the transportable charging station. Since electric vehicles have less mileage than traditional fuel vehicles, electric buses look for
fixed charging piles or transportable charging stations to charge them.

![Figure 2. Update mode for the per-generation particle location.](image)

(1) Short battery range. At present, the cruising range of electric vehicles is mostly 350 kilometers, which is less than that of traditional fuel vehicles. And there is insufficient power in the exercise. Therefore, in the design process of the VRP-SMCP model, we should consider the starting point and the remaining power to complete the transportation.

(2) Long charging time. For electric buses, it is generally considered to use DC fast charging, which is quickly charged at an hour left. Although DC fast charging is already faster than AC slow charging, it is still much longer than conventional fuel vehicles.

4.3. VRP-SMCP Model Solution
Considering the network optimization of charging piles and transportable charging stations, mainly the site selection of bus stations and the planning of transportation path. Model test on a processor of 2.7 Ghz Intel Core i5, memory of 5GB 1867MHz DDR3, write a particle group algorithm program to solve the VRP-SMCP model using Matlab software, the particle group algorithm parameter setting as shown in table 2.

| Parameter setting     | Parameter choice |
|-----------------------|------------------|
| Learning factor       | C=0.5            |
| Group size            | M=100            |
| Endurance mileage     | P=150            |
| Running speed         | G=45             |
| Manned number         | D=100            |

The program of the algorithm is repeated 3 times, and the minimum of the objective function optimization result is taken as a satisfactory solution. The algorithm results of these 3 times are shown in table 3.

| Test number | Objective function |
|-------------|--------------------|
| 1           | 1368.24            |
| 2           | 1365.37            |
| 3           | 1367.02            |
| 4           | 1365.86            |
As can be seen from table 3, the calculation result of the second experiment in the three repeated experiments is 1365.37, which is the smallest among all the experimental groups. Therefore, 1365.37 is considered to be the optimal satisfactory solution. In the optimization process of particle swarm optimization algorithm, the optimal satisfactory solution is obtained at the 1356th iteration, and the variation trend of the objective function value with the number of iterations is shown in figure 3.

In this paper, an 80km*100km square area is simulated to optimize the network, and the data simulation operation is realized by using the RandBetween function of Excel software according to the actual situation. Considering the existence of charging piles and charging stations, it is reasonable to choose this area for simulation research. Its position is shown in figure 4.

After several simulation tests, the second route is optimal, as shown in figure 5.

From the results of path optimization, it is not difficult to find that when the vehicle undertakes a remote transportation task, it must enter the public charging service facilities for rapid charging in transportation, otherwise it cannot be returned smoothly. For example, when electric bus 1 performs a transport task, it seeks a fixed charging pile for charging before returning, while electric bus 3 does not look for a charging station for charging. Of the four cars, three chose to go to a fixed charging pile for charging, and only one chose to charge at a mobile charging station. The reason is that the service fee of mobile power stations is 65% higher than fixed charging piles. And the number of transportable charging stations is less in the setting of fixed charging piles.
5. Conclusion
In this paper, a path planning model for transportable charging stations is proposed. In this model, particle swarm optimization algorithm is used to calculate the optimal location of the path, and the demand points are correlated with the grid map to calculate the traffic demand in each grid. Through multiple iterative calculations, the value of the second objective function is selected as the optimal path. Compared with the fixed charging pile, the portable charging station can optimize the position of the existing fixed charging pile and save space, and relieve the pressure of insufficient space. The establishment of portable charging stations will enhance the public’s purchase intention of electric vehicles, realize convenient and fast charging in emergency conditions. And it improves the overall utilization efficiency of portable charging stations.

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