The Location of Electric Vehicle Charging Station Based on TLBO Optimization Algorithm

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Abstract. With the large-scale application of electric vehicles, the construction of electric vehicle charging stations has become a prerequisite for urgent needs. In this paper, TLBO optimization algorithm is proposed. The optimal model of the location and the constant volume of the charging station is established based on the weighted distance and minimum distance from the user to the charging station. Based on the layout of the district network in the planning area, the construction plan of the electric vehicle charging station in the planning area is studied. Through a case study of a planning area, the results show that the TLBO optimization algorithm is applied to the location and constant volume of electric vehicle charging stations, with accurate calculation, rapid convergence, and good global optimization performance.

1. Introduction
As a zero-emission and green and energy-saving transportation vehicle, electric vehicles have received the attention of government departments and environmentalists since its introduction. However, due to its limited battery capacity, electric vehicles must be charged after traveling for a distance. As an energy supply system for electric vehicles, the charging station plays an extremely important role. Its rational layout in the city directly affects the efficiency of electric vehicle users. At present, many experts and scholars at home and abroad put forward constructive methods and suggestions for the location planning of electric vehicle charging stations. The literature [1-3] focuses on the factors influencing the location planning of electric vehicle charging stations and the principles to be followed when constructing charging stations. Literature [4,5] take the driving characteristics of the drivers, the public service infrastructure and the cost of the construction of charging stations into account. Literature [6] considers the traffic flow of the traffic network, and takes the minimum of network loss and the minimum node voltage deviation as the constraint conditions to carry out the optimal planning of the electric vehicle charging station. Literature [7] aims at minimizing the sum of the total cost and the network loss of charging stations in the planning area, and constructs a mathematical model for the optimal planning of the charging stations for electric vehicles.
The above documents provide a method for site selection planning of electric vehicle charging stations from different perspectives. However, in the newly planned urban areas, the planning of electric vehicle charging stations shall be based on the premise of minimum construction costs and operating costs, and the convenience of user charging should be considered. The shortest distance to the charging station and the least amount of time spent are the factors. From the user's point of view, this paper takes the shortest distance between the user and the charging station and the coverage of the charging station as the objective function. Taking into account the distribution center of the charging requirements of the electric vehicles in the planning area, the location and volume method of the charging station of the electric vehicle based on the teaching and learning optimization algorithm is proposed. Actually calculated by a new city planning area, the method is suitable for the site selection of the charging station with good results.

2. The mathematical model

2.1. Algorithm introduction

TLBO (Teaching-Learning-Based Optimization) is a new swarm intelligence optimization algorithm proposed by Rao et al. [8,9] in 2010 for solving nonlinear global optimal problems. Simulation teacher teaching process and student self-learning process, students learn each other to improve the overall class performance. This method has many advantages such as high calculation accuracy, fast convergence rate, small computational load, good global convergence for nonlinear optimization, and no constraint on variation of algorithm parameters. The algorithm has no control parameters and only needs to set the number of groups and the number of cycles. You can solve the optimization problem. The principle of using TLBO algorithm to deal with the optimization of n-dimensional space is as follows: The student representative group of a class, each individual is composed of n-dimensional variables, each represents n lessons of each student, and the number of students’ knowledge acquired is measured by the fitness function. The current best solution in the group is taught as a teacher, and brings the score of the class to the level close to the teacher. In the “learning” phase, if a student is only richer, the rest of the students learn new knowledge from them. The algorithm optimization process is shown in Figure 1.

![Figure 1. The flow chart of TLBO algorithm.](image-url)
2.2. Model establishment
To divide the planning area into districts by division, assuming that there are N districts in a new town planning area, and the number of parking spaces in each district is \( K = \{ k_1, k_2, ..., k_n \} \), The central point of each residential area is the charging demand location. The central coordinate point is shown in (1):

\[
(X, Y) = \left( \left( x_1, y_1 \right), \left( x_2, y_2 \right), ..., \left( x_n, y_n \right) \right)
\]

(1)

Considering that the electric vehicle charging stations in the planning area are mainly for the convenience of charging all users, they cannot be built outside the planning area. When a certain point is selected as the charging station construction point in the planning area, the center point of each district is to the charging station. The distance is shown in (2).

\[
D_i = \sum_{j=1}^{n} \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}
\]

(2)

According to the actual situation, the number of external demand of the charging points of the electric vehicles in each district is different. The location of the location of the charging station will shift to the partition with a large number of demand. The number of external charging piles of a certain district electric vehicle is used as the charging station. The weight coefficient of the address, its value is \( \lambda = \{ \lambda_1, \lambda_2, ..., \lambda_n \} \), so the function is shown in (3).

\[
F = \min \left( \sum_{i} (\lambda_i * D_i) \right)
\]

(3)

2.3. Constrains
The sum of the number of charging piles to be built in each charging station shall meet the requirements for the charging load of all electric vehicles in the planning area, and the number of charging piles per charging station can meet the charging requirements of electric vehicles within its coverage area:

\[
\sum P_j \geq \sum L_j \text{ and } P_j \geq L_j \quad (j=1, 2, ..., S)
\]

(4)

Among them, S is the number of proposed charging stations; \( P_j \) is the number of charging piles to be built at the j-th charging station, and \( L_j \) is the number of charging piles for the electric vehicle charging needs for the coverage of the proposed j-th charging station.

The range of the charging station location.
The TLBO program search scope should be the planned area of the planning area.

\[
\left( x_i \right)_{\text{min}} \leq x_i \leq \left( x_i \right)_{\text{max}} \text{ and } \left( y_i \right)_{\text{min}} \leq y_i \leq \left( y_i \right)_{\text{max}}
\]

(5)

3. Charging station location planning process

3.1. Main ideas
Taking the coordinates of the center point of each zone as the load demand center point of the zone, and taking the weighted distance and minimum of the center point to the proposed charging station as the objective function, using the TLBO algorithm to select in the planning area under the constraint conditions. Address, calculate the number and location of the best charging stations, and use the output as the final result of the construction of the charging station.

3.2. Location and volume calculation process
According to the above analysis, the calculation process is as follows:

1. Enter the coordinates of each partition;
(2) Enter the proposed number of electric vehicle charging stations;
(3) Enter the coordinate constraints of the proposed site;
(4) Input the external demand quantity of each district charging pile;
(5) Enter the number of iterations and the number of groups;
(6) Use TLBO optimization algorithm to calculate the coordinates of the proposed charging station;
(7) Calculation of the charging requirements for electric vehicles within the coverage and coverage of the proposed charging station;
(8) Calculate the number of electric vehicle charging piles within the coverage of the proposed charging station;
(9) Output the position coordinates, coverage of the proposed charging station for electric vehicles, and the number of charging piles to be built at each station.

Figure 2. Location and capacity calculation process.

3.3. *The location of charging piles based on TLBO algorithm*

In this paper, within the entire planning area, the calculated location of the proposed charging station must meet two conditions: the distance from the charging station to the coverage area is the shortest, and the proposed location is close to the coverage area where the external charging piles have more demand.

4. **Examples**

Take a new town planning area as an example. The planning area covers an area of 5.7km2 and the total population is 115,000. The planning area is divided into 36 blocks according to the nature of the land. The coordinates of the 36 district centers are shown in Figure 3.

Figure 3. 36 partition locations.

In the figure, the horizontal and vertical coordinate units are km.
In each of the 36 districts, there is a parking lot for each district. Figure 4 shows the distribution of parking spaces in each district.

![Parking Space Distribution](image)

**Figure 4.** 36 partition locations.

Considering that the area of the planning area is only 5.7km² and the number of charging stations is too large, construction costs and operating costs will be increased accordingly. However, for users, the time and distance to save are not many, so set at least one building. Do more to build 4 electric vehicle charging stations.

The proposed site must be within the planning area, that is, its abscissa should be in the range of (0, 3.32) and ordinate in the range of (0, 2.56). Exceeding this range indicates that the construction site is not desirable and should be rejected.

Assuming that the parking lot is the total number of cars in the planned area of the new city, the penetration rate of electric vehicles is calculated at 15%, and 15% of all electric vehicles in the subzone need to be charged at the charging station because the fast charging pile can be within 20-30 minutes. Complete charging of electric vehicles is completed, so 10 electric vehicles are set to share one fast charging pile. After calculation, the number of external charging piles in each subarea is shown in Figure 5.

![External Demand](image)

**Figure 5.** External demand of charged piles.

Set the population number to 500, the maximum number of iterations to 5000, and the overall variance to take 10^-6 as the convergence criterion. Through the TLBO algorithm, the construction number and coordinates of charging stations, their respective coverage areas and the number of charging piles in the coverage area are obtained.
Table 1. Construction index of charging station

| Construction number of charging station | Location | Coverage range | Demand number of charging pile |
|----------------------------------------|----------|----------------|-------------------------------|
| 1                                      | (1.26,1.69) | 1-36           | 128                           |
| 2                                      | (0.79,0.88) | 21-24,36       | 67                            |
|                                        | (1.72,2.58) | 1-20,22-23     | 61                            |
|                                        | (0.60,0.27) | 31-36          | 28                            |
| 3                                      | (1.05,1.35) | 21-30          | 47                            |
|                                        | (1.74,2.71) | 1-20           | 53                            |
|                                        | (0.48,0.19) | 33-36          | 23                            |
| 4                                      | (1.11,1.00) | 25-30,32       | 35                            |
|                                        | (1.44,1.80) | 17,20-24       | 21                            |
|                                        | (1.72,2.78) | 1-16,18-19     | 49                            |

According to the calculation results in Table 1, the proposed location coordinates of the charging station are marked on the partition location map, as shown in Figure 6.

Figure 6. Construction position of charging station.
The coverage of the proposed charging station is marked on the map. Since the construction of a charging station covers 36 districts within the entire planning area, no sign is made for it. Two, three, and four charging stations are built and covered. The range is marked as shown in Figure 7.

(a). One charging station coverage range.
(b). Two charging station coverage range.

(c). Three charging station coverage range.

(d). Four charging station coverage range.

Figure 7. Coverage range of charging station.

5. Conclusion

Based on the construction of the planning area, this paper first divides the planning area before the site selection and capacity allocation, and regards each district center as the electric vehicle charging load center of the district, and the user’s convenience of charging is shown by the shortest distance from the user to the charging station. The number of electric vehicle charging piles in the district is used as a weighting factor for the location of the charging station to comprehensively determine the construction location of the electric vehicle charging station. Using this as an objective function, the TLBO algorithm was used to find out the number of electric vehicle charging stations, the construction location, the coverage of each charging station, and the number of charging piles in the charging station. The optimal site selection and constant capacity of electric vehicle charging stations were achieved. In the end, the planning plan for the construction of the electric vehicle charging station in the entire planning area will be obtained.
The practical example shows that the TLBO optimization algorithm and the model proposed in this paper have certain feasibility. However, this article mainly considers the factors related to electric vehicles, such as the distance between the user and the charging station, external requirements of the district charging pile, and the structure of the planning area. The factors related to the distribution system, such as the distribution transformer capacity, are closely related to the construction of the charging station. The factors have not yet been considered. This will be further studied in the follow-up work.

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