How to Realize the Comprehensive Application of Electric Vehicles

Xiaolin Zhou, Ziheng Jiao and Jinlin Hu

School of Information Engineering, Chang'an University, Xi'an, Shaanxi, 710000, China

Keywords: Electric Vehicles, Comprehensive Application, 0-1 Planning, Cluster Analysis

Abstract: In order to realize the comprehensive application of electric vehicles, we have established models in turn, and then determine the the key factor in the development of electric vehicles. The final network of charging stations needs to achieve the minimum cost of building stations and the most convenient charging, so we established an optimization model of the distribution of charging stations. We describe it as a 0-1 planning problem. According to the characteristics of the two charging stations, a distribution model is established separately. Among them, the super charging stations are all built along the highway, and the distance of the station is determined by the two indicators of traffic volume and the importance of the section of the highway, which is measured by the number of edges in the complex network. The improvement is in selecting the right site in the final network. The development of electric vehicles can be seen as a process of competition with traditional cars, so a competitive exclusion model can be used to establish an electric vehicle development model, and the relationship between the two's inherent growth rates is used to determine the competitive advantages of the two. We selected the country's per capita GDP, population density, pollution index and Gini coefficient as factors affecting the national electric vehicle development model, using distance to measure the similarity between various countries, and establishing a classification model based on q-type cluster analysis.

1. Introduction

At present, the world is committed to reducing the use of fossil fuels, including automobile gasoline [1]. Considering environmental and economic factors, consumers have begun to switch to electric vehicles. Some countries have seen the potential of electric vehicle development [2]. In the United States and other countries, more affordable release of the all-electric Tesla Model 3 has created records of pre-orders and long-term waiting lists. To further accelerate the transition to electric vehicles, some countries, including China, have announced that they will ban gasoline and diesel in the next few years use electric cars [3]. However, it is a long process for electric vehicles to replace traditional cars as the mainstream transportation mode, and establishing a perfect electric vehicle network structure [4]. Due to the impact of many practical factors such as limited resources, consumers need to spend a long time to complete the transformation [5]. The location and convenience of the charging station are the key factors that affect the willingness of those early users and ultimately mainstream consumers to actively change their consumption concepts [6].

2. Optimization model and evolutionary development model of charging station distribution

2.1 Optimization Model of Distribution of Charging Stations

According to the characteristics of the two charging stations, the mathematical models of the destination charging station and the super charging station are established respectively.

2.1.1 Destination charging station model

(1) Model establishment

For the destination charging station, we divide it into two types according to different countries, one is a country like the United States mainly based on family diaspora, the charging station is built directly at home, and the other is similar to South Korea and China [7]. To establish a public charging station for users to use in a country where residence is predominant [8]. In this analysis, the United States faces a relatively simple problem of building a station. Here we will focus on solving the problem of how to build a station in a country like South Korea [9].

Suppose there are m electric cars in total and the location is$(x_i, y_i)(i = 1,2, \ldots, m)$. There are n charging stations to be established, the location is$(u_j, v_j)(j = 1,2, \ldots, n)$.

After full thinking, we set the decision variable to

$$x_{ij} = \begin{cases} 1, & \text{the i electric car goes to the j charging station for charging.} \\ 0, & \text{the i electric car cannot be charged at the j charging station.} \end{cases}$$

According to the goals to be achieved by the finally established charging network, we give two objective functions: the minimum number of charging stations and the minimum distance from all electric vehicles to the charging station:

$$\min Z_1 = n$$

$$\min Z_2 = \sum_{i=1}^{m} dis_i$$

After analysis, the optimized model of the distribution of charging stations is as follows:

$$\min Z_1 = n$$

$$\min Z_2 = \sum_{i=1}^{m} dis_i$$

$$s.t. \begin{cases} \sum_{j=1}^{n} x_{ij} = 1 \quad \mathrm{i} = 1,2,\ldots,\mathrm{m} \\ s_j = \sum_{i=1}^{m} x_{ij} \quad j = 1,2,\ldots,n \\ a \le s_j \le b \\ dis_i = \sum_{j=1}^{n} x_{ij} d_{ij} \quad i = 1,2,\ldots,m \\ dis_i \le R \\ d_{ij} = \sqrt{(x_i - u_j)^2 + (y_i - v_j)^2} \quad i = 1,2,\ldots,m; j = 1,2,\ldots,n \\ u_{max} L \ge s_j \bar{u} \\ x_{ij} = 0 \text{ or } 1 \end{cases}$$

(2) Algorithm design

A. K-means clustering algorithm is used to cluster all vehicles into n categories according to their mutual distance. The center of each category is used as the initial position of the charging station.If the j initial position of each center is not in the area of the buildable charging station, then adjust to the closest position of the buildable station, and record its adjustment distance $\mathrm{m}d_j$. Among them, K-means clustering is to randomly select k objects as the initial clustering center, then calculate the distance between each object and each seed clustering center, and assign each object to the clustering center closest to it. The collection of cluster centers and the objects assigned to the cluster centers represents a cluster [10]. Once all objects are assigned to a class. The cluster center of each cluster will be re-based on the existing objects in the cluster calculation. The new cluster center is generally the average of all points in the corresponding cluster.

B. Determine whether the constraints are met $a \le s_j \le b$ and $dis_i \le R$; if j after the initial adjustment of each center, it is allowed to $dis_i \le R + md_j$, indicating that the radius can be relaxed.$dis_i > R$ of electric cars are assigned to the nearest charging station. The constraints will not be met $a \le s_j \le b$ remove the class and divide it into classes that satisfy the condition.

C. Determine whether the constraint is met $u_{max}L \geq s_j\bar{u}$, if not satisfied, reduce the j the electric vehicles with the furthest distance from each charging station are divided into categories that satisfy the constraints until the conditions are met.

D. For each type of center(u_j, v_j) perform fine adjustment, if the total distance decreases, the fine adjustment is effective, otherwise it will not move.

E. Repeat 2 and 3 to perform iterative calculations until the total distance no longer decreases, and all constraints are met.

2.1.2 Super charging station model

Since the super charging station is designed for long-distance travel, for users to quickly charge and use fast, so we will build the super charging station along the road. For the establishment of the super charging station, we consider two issues: one is to build, the other is the number of charging piles in the charging station.

Since the highway is always in a complex highway system, rather than a separate highway, we use a complex network method to consider this problem.

Consider setting up the distance of a charging station on the highway formed between any two nodes in a complex network composed of a national highway network. We can use two methods to establish the distance between stations, one is to determine the traffic flow measured by actual data; the other one is based on the importance of the section of road in the network.

The importance of each side of a complex network can be measured by the number of edges, which is defined as the ratio of the number of paths passing through that edge to the total number of shortest paths in all the shortest paths in the network, there are

$$B_k = \frac{\sum_{1 \leq i < j < N} n_{ij}(k)}{\sum_{1 \leq i < j < N} n_{ij}}$$

If we consider both the traffic flow and the number of side influences to affect the distance between the station and the number of charging piles, it will be too tedious. The number of charging piles in the charging station. The selection principle of the distance d (unit: miles) is as follows:

$$d = \begin{cases} 50, B_k < 10\% \\ 60, 10\% \leq B_k < 20\% \\ 70, 20\% \leq B_k < 30\% \\ 80, 30\% \leq B_k < 40\% \\ 90, 40\% \leq B_k < 50\% \\ 100, 50\% \leq B_k \end{cases}$$

Determination of the number of charging piles: Suppose that a certain section of road is S miles long, and the daily traffic volume (only 12 hours during the day) is K. Assume that a fast charging station is built at a distance of d kilometers, and there are p charging stations for each charging station. Then the number of charging stations in this section is

$$\text{num} = \left\lceil \frac{S}{d} - 1 \right\rceil$$

Among them $\lceil x \rceil$ indicate right x rounded up.

Charge times are

$$\text{c} = \left\lceil \frac{S}{170} - 1 \right\rceil$$

Investigate the relationship between the number of charging stations, the number of charging piles and the traffic flow, because each car is charged for half an hour, according to the service capacity

$$\text{num} \times \text{p} \times 24 = \text{K}$$

Considering that the traffic flow is not uniform every day, there are times when there are busy and there are few vehicles. We count the one-way traffic flow every 12 hours during the day and every half hour$x_1, x_2, \ldots, x_{24}$, according to the statistical data, it is usually normally distributed, and its mean and standard deviation are calculated as

$$\overline{x} = \frac{\sum_{i=1}^{24} x_i}{24}, \sigma_n = \sqrt{\frac{\sum_{i=1}^{24} (x_i - \overline{x})^2}{23}}$$

Due to normal distribution $X \sim N(\mu, \sigma^2)$ data satisfaction $P\{X - \mu \leq 1.65\sigma\} = \Phi(1.65) = 0.95$. Choose a 95% probability of being busy, then the traffic flow for half an hour is:

$$P\{X \leq \overline{X} + 1.65\sigma_n\} \approx 0.95$$

So traffic $K = 24 \times \overline{X}$. We select the upper bound of the vehicle $K' = 24 \times (\overline{X} + 1.65\sigma_n)$.

The number of times the electric vehicle is charged $c = \left\lceil \frac{S}{170} - 1 \right\rceil$, then

$$\text{num} \times \text{p} \times 24 = 24 \times (\overline{X} + 1.65\sigma_n) \times c$$

Therefore, the number of charging piles is

$$\text{p} = \left\lceil \frac{\overline{X} + 1.65\sigma_n}{num} \times c \right\rceil$$

Suppose that the road transportation network has n sections of roads, each sectionS_i. The distance between charging stations is d miles. The total number of charging stations is

$$Total_1 = \sum_{i=1}^{n} \left\lceil \frac{S_i}{d} - 1 \right\rceil$$

The total number of charging piles is

$$Total_2 = \sum_{i=1}^{n} \left\lceil \frac{\overline{X_i} + 1.65\sigma_{ni}}{num_i} \times c \right\rceil$$

2.2 Evolutionary Development Model of Charging Station Distribution

2.2.1 Evolution model of the destination charging station

We assume that the established charging stations will not be dismantled, that is, continue to expand and improve on the basis of the original charging network, that is to say, the charging station network at different stages is formed by selecting a certain number of charging stations in the final network.

Assuming that electric vehicles account for 100%, there are n fast charging stations in the country, the positions are $(u_j, v_j)(\text{j} = 1,2, \ldots, \text{n})$. Consider when the proportion of electric vehicles is η time (e.g.η=30%), the total number of electric vehicles is $m_1 = \lceil m \times \eta \rceil$, m is the total number of all electric vehicles. Its position is$(x_i, y_i)(\text{i} = 1,2, \ldots, m_1)$the charging pile of each charging station is still the previous L (for example, L=9), we select all n charging stations$n_1 = \lceil n \times \eta \rceil$, which specific charging stations are selected, we use the 0-1 variable z_j. So set 0-1 variable

$$z_j = \begin{cases} 1, & \text{selection of j charging station} \\ 0, & \text{j charging station is not selected} \end{cases}$$

Set auxiliary decision variables

$$x_{ij} = \begin{cases} 1, & \text{the i electric car goes to the j charging station for charging.} \\ 0, & \text{the i electric car cannot be charged at the j charging station.} \end{cases}$$

Total number of charging stationsn_1 has been determined, so as long as the objective function has the smallest distance, there is

$$\min D = \sum_{i=1}^{m_1} dis_i$$

After analysis, the evolution model of the destination charging station can be established:

$$\min D = \sum_{i=1}^{m_1} dis_i$$

$$s.t.\begin{cases} \sum_{j=1}^{n} z_j = n_1 \quad z_i = 1, i \in D \\ \sum_{j=1}^{n} x_{ij} = 1 \quad i = 1,2,\ldots,m_1 \\ x_{ij} \le z_j \quad i = 1,2,\ldots,m_1; j = 1,2,\ldots,n \\ s_j = \sum_{i=1}^{m_1} x_{ij} \quad j = 1,2,\ldots,n \\ u_{max} L \ge s_j \overline{u} \quad j = 1,2,\ldots,n \\ dis_i = \sum_{j=1}^{n} x_{ij} d_{ij} \quad i = 1,2,\ldots,m_1 \\ d_{ij} = \sqrt{(x_i - u_j)^2 + (y_i - v_j)^2} \quad i = 1,2,\ldots,m_1; j = 1,2,\ldots,n \\ dis_i \le R' \quad i = 1,2,\ldots,m_1 \\ x_{ij} = 0 \text{ or } 1 \quad y_j = 0 \text{ or } 1 \end{cases}$$

2.2.2 Evolution Model of Super Charging Station

For the super charging station, we assume that the road network is unchanged. The distance between the super charging station and the station is the same, so the location of the super charging station does not change when all electric vehicles are used. Goals.

Suppose that the traffic volume of a certain section of highway per hour obeys the mean value $\overline{x}_{new}$, Normal Distribution with Sample Standard Deviation σ_{new}, the number of charging stations on this highway is num, then the number of charging piles at each charging station of the highway is

$$p_{new} = \left\lceil \frac{\overline{x}_{new} + 1.65\sigma_{new}}{num} \times c \right\rceil$$

3. Electric vehicle development model

3.1 Overview and Analysis of the Model

In order to build a national timetable for the development of electric vehicles, we mainly start from the market competition between electric vehicles and traditional vehicles. Since electric vehicles and traditional vehicles have advantages and disadvantages in terms of capacity, price, environmental protection, and cost of ownership, there is competition, so it can be seen that there is a competitive relationship between the sales of electric cars and traditional cars. From this we established a competitive exclusion model.

3.2 Competition Exclusion Model

Suppose $x_1(t)$ is the number of electric cars that change with time t,$x_2(t)$ is the number of traditional cars that change with time t, r_1 for the inherent growth rate of electric vehicles,r_2 for the inherent growth rate of traditional cars, N_1 for the maximum capacity of electric vehicles, N_2 for the maximum capacity of traditional cars,α for the competitive advantage of traditional cars relative to electric cars, β for the competitive advantage of electric vehicles relative to traditional cars, then

$$\begin{cases} \frac{dx_1}{dt} = r_1 x_1 (1 - \frac{x_1}{N_1} - \alpha \frac{x_2}{N_2}) \\ \frac{dx_2}{dt} = r_2 x_2 (1 - \frac{x_2}{N_2} - \beta \frac{x_1}{N_1}) \end{cases}$$

Suppose $N_1 = N_2$ then$\begin{cases} \alpha < 1 \\ \beta > 1 \end{cases}$.

4. Classification model of development models of electric vehicles and charging stations

4.1 Overview and analysis of the model

In order to propose a classification system for the development model of a national electric vehicle, we selected the four indicators of GDP per capita, population density, pollution index and Gini coefficient as the factors affecting the development model of a national electric vehicle. Here we establish a cluster analysis based on Q-type the clustering model of method treats each country as a point in the p-dimensional space. The above four indicators are used as four dimensions, and the distance is used to measure the similarity between various countries.

4.2 Clustering Model

In cluster analysis, the Mahalanobis distance is used to measure the similarity between different countries.

$$\mathrm{d(x,y)} = \sqrt{(x-y)^T \Sigma^{-1} (x-y)}$$

Among them $\mathrm{x,y}$ four-dimensional column vectors determined by the above four indicators for two different countries.

For the similarity measure between classes, we use the shortest distance method.

$$\mathrm{D}(G_1, G_2) = \min_{\substack{x_i \in G_1 \\ y_i \in G_2}} \{x_i, y_i\}$$

Among them G_1, G_2 these are two different classes.

5. Conclusion

For the distribution model of the destination charging station, we describe the problem as a 0-1 planning problem, which greatly simplifies the problem and establishes a more concise and effective optimization model; for the super charging station, we use the importance of the road to determine the distance to build the station. Introduce the concept of marginal number to describe quantitatively, and at the same time use the traffic flow to determine the number of charging piles in the charging station, which solves the problem of building a super charging station well; establishes an ideal charging network evolution development model; uses competition The exclusion model reasonably describes the development process of electric vehicles, and it is also more reasonable for the determination of parameters.

References

[1] Sheng Wenjun, Wang Hongyi, Zhang Kequan. Research on the development of new energy photovoltaic vehicle charging stations [J]. Times Automobile, 2020, (04): 39-40.

[2] Qian Zhiyuan, Ren Yuanyuan, Chen Hua, Guangxu, Feng Tao, Qian Bin. The construction and interpretation of the comprehensive energy supply service station construction specifications [J]. Smart City, 2020, 6(03): 16-18.

[3] Zhou Jianwei, Wu Fangjie. Research on charging technology of new energy electric vehicles [J]. Decision exploration (middle), 2020, (01): 96.

[4] Qiao Mingya, Wang Dengdeng. Research on site selection evaluation of special charging station for new energy logistics vehicles [J]. Journal of Zhejiang Wanli University, 2020, 33 (01): 26-30+59.

[5] Yang Wei, Wang Yan. Modeling of electric vehicle charging station location optimization [J]. Journal of Changchun University of Technology, 2019, 40 (06): 553-556.

[6] Ning Hong, Wu Wei, Luo Yu. Standardization of electric vehicle charging stations——Taking the construction of electric vehicle charging facilities in Hefei as an example [J]. Journal of Anhui Electrical Engineering Vocational College, 2019, 24(04): 34-38.

[7] Pan Long. Research on the optimization of electric vehicle charging facility layout based on charging selection behavior [D]. Beijing Jiaotong University, 2019.

[8] Luo Jiangpeng. Research on the optimization of the location and volume of electric vehicle charging stations [D]. Jiangsu University, 2019.

[9] Feng Xiaoshan. Design and optimization of electric vehicle charging station [D]. Yanshan University, 2018.

[10] Li Siyang. Research on the location strategy of electric vehicle charging stations [D]. University of Electronic Science and Technology of China, 2018.