The study on the Layout of the Charging Station in Chengdu

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Abstract. In this paper, the comprehensive analysis of the factors affecting the layout of the electric car, considering the principle of layout of the charging station. Using queuing theory in operational research to establish mathematical model and basing on the principle of saving resource and convenient owner to optimize site number. Combining the theory of center to determine the service radius, Using the Gravity method to determine the initial location, Finally using the method of center of gravity to locate the charging station’s location.

1. Introduction
Electric vehicle charging and changing equipment is an important supporting facility of electric vehicles. It is one of the main factors that affect the development and promotion of the electric vehicles. Only by improving the supporting facilities can the development of electric vehicles be promoted. Chengdu city is one of the 5 pilot city of third group of ten city 1000 project, but the development of the electric vehicles in Chengdu city is slow and stagnant due to the imperfect development of charging facilities. In order to promote the development of electric vehicles in Chengdu City, this paper combines the existing research results at home and abroad and puts forward its own opinion, theoretical model is established and applied to the practice, which can provide the reference for the location of charging facilities of the electric vehicles.

2. The Planning of Building the Charging Facilities Station
The research of this thesis is planned on the basis of the standard charging station and calculates it based on the data about the car ownership and charging demand of Chengdu City in the paper. Prediction on the charging demand for electric vehicles in Chengdu. First of all, this paper should confirm the service capacity and scale construction of the standard charging stations and use the mathematical models to plan and confirm the number of construction of charging.
stations.

2.1 Scale of the standard charging station
Combining the scale of the gas station to confirm the scale of the standard charging station.[1] The formula of the service capability is shown as the following:

\[ C = M \cdot \mu \cdot t \]

In the formula, C - the maximum service capability of the standard charging station, set/ day
M - the sets of the facility (Battery replacement 12 sets, DC charging 4 sets), \( \mu \) - the service rate (theoretically, 4 units/h, actually, 3 units/h), t - the working time (theoretically, 24h, actually, 16h)

Considering the actual situation of the gas station, the scale of the standard charging station can be obtained as shown in Table 1.

| Charging mode | The set of the DC charging | The set of the battery replacement | Maximum service capability | Actual service capability |
|---------------|----------------------------|-----------------------------------|---------------------------|--------------------------|
| Standard units | 4                          | 12                                | 1440 units/day             | 768 units/day             |

2.2 Queuing Model Construction and Solution
2.2.1 The Analysis and Description of the Problem
The electric car that is lack of electricity and needs to be charged on the road, this process is a random process. According to the experience, the process of charging demand for electric vehicles meets the three major characteristics of the Poisson distribution introduced above. So the paper can use Poisson flow to describe the law of the electric vehicle charging demand. When two customers arrive at the service station, the time interval T satisfies the time negative exponential distribution, which can be described. According to the principle of queuing theory \[2\] and the full analysis of the arrival of electric vehicles at the service station, this paper makes the following hypothesis:

(1) The charging time of each electric vehicle follows a negative exponential distribution;
(2) Each electric vehicle charging and system capacity limits service system;
(3) The number of electric vehicles waiting to be charged can not exceed a certain number, so that the number of electric cars waiting in line can not exceed 5 units ;
(4) Queueing time can not exceed a certain period of time, or the waiting time is too long, it will affect the owner's trip. The waiting time is not more than 15 minutes or 0.25 hours.

2.2.2 The Building of the Model
The queuing model has mainly loss model, waiting model, mixed model, according to the above analysis of the charging system, this paper is standard multi-service waiting model M/M/C, that is Poisson input, negative exponential distribution, waiting queue model of C service desk, service in accordance with the rules first-come -first -served and customer source is infinite.

When the customer arrives at the service desk, the time interval follows the Poisson distribution of the parameter, and the service time obeys the negative exponential distribution of the parameter. The average service rate of every table cloth assisting each service desk is \( c \mu \) or \( n \mu \), \( \rho = \frac{\lambda}{c \mu} \), is average utilization rate of the service institutions, that is service intensity. When \( \rho > \frac{1}{c \mu} \), the system does not end up in an infinite queue. The system
transition state diagram of model M/M/C is shown as the system state transition diagram of the following 1. M/M/C model:

![Transition State Diagram](image)

**Fig1:** The system state transition diagram 1M/M/C model

In the state transfer system state diagram, 0 indicates that there is no electric vehicle charging station and charger idle, transferring state 0 to state 1 represents a car arrives at the service institution, 1 charger work, others idle, the transferring rate is $\mu P_1$, similarly, The analysis of state n shifts to state n+1, there are 2 cases: first is when $n \leq C$, the N service desk work, state transferring rate is $n\mu P_n$, second is when $n > C$, C electric cars are served, N-C electric cars waiting in line, the state transferring rate is $C\mu P_n$.

The steady-state equilibrium equation of the system is:

$$
\mu P_1 = \lambda P_0 \\
(n + 1)\mu P_{n+1} + \lambda P_n = (\lambda + n\mu)P_n, (1 \leq n \leq c) \\
c\mu P_{n+1} + \lambda P_{n-1} = (\lambda + c\mu)P_n, (n > c)
$$

$$
\sum_{n=0}^{\infty} P_n = 1 \\
\rho = \frac{\lambda}{c\mu} \leq 1
$$

In the formula, and therefore, the probability of the system state can be obtained by recursion:

$$
P_0 = \left[ \sum_{n=0}^{c-1} \frac{1}{n!} \left( \frac{\lambda}{\mu} \right)^n + \frac{1}{c!} \left( \frac{\lambda}{\mu} \right)^c \left( 1 - \frac{\lambda}{c\mu} \right)^{-1} \right]^{-1}
$$

The operating index of the system is:

$$
L_q = ((c - 1)!(c\mu - \lambda)^{c-1} \lambda \mu (\frac{\lambda}{\mu})^c) P_0, \quad L_s = L_q + \frac{\lambda}{\mu}, \quad W_q = \frac{L_q}{\lambda}, \quad W_s = \frac{L_s}{\lambda}
$$

In the formula, PO is the probability that the system state is 0 at the moment T, and $\lambda$ is the average arrival rate for the electric vehicle to the charging station, Unit is the unit per hour, and the formula is as follows:

$$
\lambda = \frac{B_0 \cdot K}{N \cdot T}
$$

In the formula, $B_0$-total demand for vehicles, unit is car number/ day $K$-Service vehicles account for 0.9 of the total amount of services in the whole day $N$-number of the urban construction sites
The actual time for the service at the charging station is 16 hours. The total charge charging demand and the number of the urban charging station are the factors which influence city electric vehicle arrival rate, while the demand is gradually increasing with the development of electric vehicles, so the city can adjust number of charging \( \mu \) is the average service rate of vehicles per hour, the average service rate of the fast charging station is 3 vehicles per hour, The average service rate of the battery charging station is 4 units/hour, taking into account the influence of external factors and convenient calculation, the paper will value the average service rate of 3 vehicles per hour.

Because the private car demand is bigger on weekends, in order to avoid queueing on weekends and charging time too long, which will influence the residents' travel. Here, the charging demand of the residents weekend needs to be ensured, so meeting the charging demand of 2015 year is regarded as an aim of building station of the paper, according to the standard of charging station service capacity is 768 vehicles per day, In order to save energy and capital, the minimum number of stations in Chengdu is planned, and the number of stations, average service capacity, service intensity and service level are as following scale of station construction of table 2.

| The minimum number of stations | Average arrival rate | Service intensity | Average queue length | Average waiting time |
|--------------------------------|---------------------|-------------------|----------------------|---------------------|
| 12                             | 43.2                | 0.91              | 5.97                 | 0.14h               |

Because the average queue length is 5.97 and greater than 5 does not meet the prerequisites, the minimum number of stations should be increased, by gradually increasing the number of stations to gain the most appropriate number of building station to meet the service requirements as shown in table 3.

| The minimum number of stations | Average arrival rate | Service intensity | Average queue length | Average waiting time |
|--------------------------------|---------------------|-------------------|----------------------|---------------------|
| 13                             | 39.8                | 0.83              | 4.37                 | 0.11h               |

Because the average queue length is 4.37, less than 5, and the average waiting time is 0.11 hours, less than 25 hours, the most suitable station scale is 13 station. With the same method, the paper can get the station scale of public fast charging station in the coming years, as shown in table 4.

| Year                  | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------------------|------|------|------|------|------|------|
| The number of the station | 13   | 20   | 33   | 56   | 81   | 116  |

3 The Planning of the Location

The idea of planning the location of the charging station is: firstly, to use the central ground theory to divide the service area and reduce the overlap of facilities between the service areas and avoid unnecessary waste of resource allocation. And then make use of gravity model approach to firstly choose primary site in each primary service area, but the primary site in
practice is not necessarily can be achieved, so you can choose n possible locations in the coordinates near the possible sites as an alternative site, finally focus on the model to determine the final location.

3.1 The Central Ground Theory Determining the Service Radius

According to the central gravity theory, the paper regards 2015 as one-level central place and 2020 as 2-level center place. The same level is mutually excluded into a honeycomb distribution; the different levels are nested with each other, and the higher level contains the lower level.

Formula based on service radius:

$$R_{\text{max}} = \frac{V}{t} \bullet u$$

In the formula, $R_{\text{max}}$ - Maximum radius of service km

- $V$ - Average speed of the car km/h (30km/h)
- $t$ - the maximum time of the finding the center place (10min)
- $u$ - influencing factors (0.8)

So $R_{\text{max}} = 4$ km, According to the formula of regular hexagon area is 41.52km, the center ground area is 41.52km. So the paper gets the lowest level central area and the one-level center place. The main research object of this paper is the public fast charging station, and the main service objects for public fast charging station are the traffic. Taxi distribution in the urban areas is more scattered, so the paper only needs to study the object, that is, service areas of universities, hospitals, shopping malls, traders Hotel. The user distribution of tourism scenic spot as the research object to represent the center area, the number of users is evenly distributed according to the size of the area, for private cars is evenly distributed according to the size of the residential area. The Tianfu Square is used as the coordinate origin, and the center of the one-level center is shown in figure 2.

3.2 To Determine the Primary Site of the Center with Gravity Model Method

![Figure 2. Central service scope centers](image)
Here, this paper respectively calculates one place to meet the one-level central level, that is, to accord with the charging demand in 2015, and to meet the two-level center place, that is, to meet of the coordinates of the charging demand in 2020. First calculate the coordinates that meet the one-level center place, and then take the demand and coordinates of each point into the formula of gravity model method:

The primary site is(-0.83, -1.15), exactly falls in the residential area, operability is very low in Figure 3, the alternative location the residential area, so combining the gravity point near the gas station which has built to choose the location to realize resource utilization. In the area near the gas station, there are the oil gas station (Gaosheng Bridge), Sinopec gas station (Qingshui River gas station), Sinopec (hongpailou gas station), regarding three gas stations as alternative sites. As shown in: Figure 1 is Sinopec gas station (Qingshui River gas station); 2 is Sinopec (hongpailou gas station); 6 is Petro China gas station (Gaosheng Bridge Road).

3.3 Center of Gravity Method to Confirming the Final Location

The gravity center model is designed to solve the location problem of two or more facilities, Make the demand point to the weighted distance of its nearest facility point and the Tc minimum, and the formula of the model is as follows:

\[ \min T_c = \sum_{i} E_i d_i \]

In the formula, n- the number of the optional sites
m- the number of the demand point
\( E_i \) - the demand intensity of the demand point i to the facility point j
\( d_i \) - the shortest distance of the demand point i to the facility point j.

According to Euler formula is

\[ d_i = \sqrt{(X_i - x)^2 + (Y_i - y)^2} \]

Regarding the minimum distance between user and service points as the location index, according to the formula 3-2 of the gravity center method, making the required data applied into the formula to get the shortest distance of the alternative sites: S Qingshui River =1987.5, S Hongpailou =2013.2 , Tgaoshengqiao =1635.4. Therefore, finally the paper determines Petra China(Gaosheng Bridge Road gas station).

The location of the charging station in 2015 has reached the most central location, and the others are scattered from the center to the surrounding area and can be gained the location in the same way. With the increase of the number of electric cars, in order to meet its needs, the construction of charging stations will be increased every year. The two-level center places will be filled with Chengdu by 2020 as shown in Figures 4 and 5.

Figure 3, the alternative location the residential area
Electric vehicle charging system is an important basic support system of electric vehicles, and also is an important link in the process of commercialization and industrialization of electric vehicles. In this aspect, it is necessary for the government to introduce corresponding policies to compulsorily promote, which helps to effectively accelerate the development of electric vehicles. For example, the government can introduce a policy for Sinopec, PetroChina and the state grid and other large state-owned enterprises and electric vehicle batteries businesses joint "three policy" and unify battery model as possibly as; the government can be free to construct AC charging pile in the area or parking lot, let private car etc normally charge from Monday to Friday and reduce traffic congestion situation.

4. Conclusion

(1) The paper combines the related theory of choosing the location to study the plan of the layout of the charging station of vehicle cars, the areas that are worth affirming are as follows:

(2) After determining the standard charging station model, the queuing theory is applied to optimize the number of stations.

(3) Using the central gravity theory to determine the service radius, using gravity model approach to determine the first location, the central gravity method determines the final location. The combination of the three methods achieves the scientificalness and accuracy of site selection.

(4) But the location of the electric vehicle charging station involves many models, constraints and many uncertain variables. It is a very complicated project. This thesis is based on the present urban construction layout of Chengdu city. With the development of economy, if the layout of the city is changed into satellite layout, the prerequisite of the study will be changed.

References

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