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Research on Location Selection of Urban Electric Vehicle Swap Station

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Abstract

In order to solve the pain and difficulty of charging electric vehicles (electric vehicles here only refer to two-wheel electric vehicles, and the following electric vehicles refer to two-wheel electric vehicles), a battery swap mode has emerged, which can not only achieve fast charging, but also Moreover, the improvement of the technology of the substation can realize safe charging. However, the construction of electric vehicle swap stations is still in the preliminary exploration stage, and there is still no complete method system. With the goal of maximizing the annual operating income of the construction operator and minimizing the user's power replacement cost, build an urban electric vehicle replacement power station site selection model, and design a genetic algorithm based on the model to determine the optimal number of facilities site selection, location, and site configuration battery Quantity. This method not only considers the needs of electric car users, improves the convenience of users to change electricity, but also reduces costs for construction operators, avoids waste of resources, and provides an important reference for urban electric vehicle replacement station planning.

Keywords

Electric Vehicle; Location Selection; Genetic Algorithm.

1. Introduction

In recent years, the development of urban electric vehicles in my country has been very rapid. According to data compiled by the Wind Foresight Industry Research Institute, since 2009, the number of domestic electric vehicles in society has almost shown a linear upward trend, with an average annual increase of about 20 million. In 10 years, the domestic electric vehicle ownership has changed from less than 100 million. Increased to 300 million vehicles. The total population of our country is about 1.37 billion people, so about 4.6 people have an electric bicycle. The average household size is about 3 people, so every 3 households have 2 electric bicycles. Electric vehicles are most widely used in industries such as express delivery and instant distribution. According to data from Meituan Takeaway and Ele. Meituan, the number of Meituan takeaway riders in 2019 exceeded 4 million, and Ele.me registered over 3 million riders. According to the data compiled by the Huajing Industry Research Institute of the Ministry of Industry and Information Technology, my country's electric vehicle sales are showing a fluctuating growth trend. At the end of 2019, my country's electric vehicle sales were 34.64 million units, an increase of 12.1% year-on-year. In the first six months of 2020, the profit from electric vehicle sales reached 1.67 billion yuan, a year-on-year increase of 31.6%.

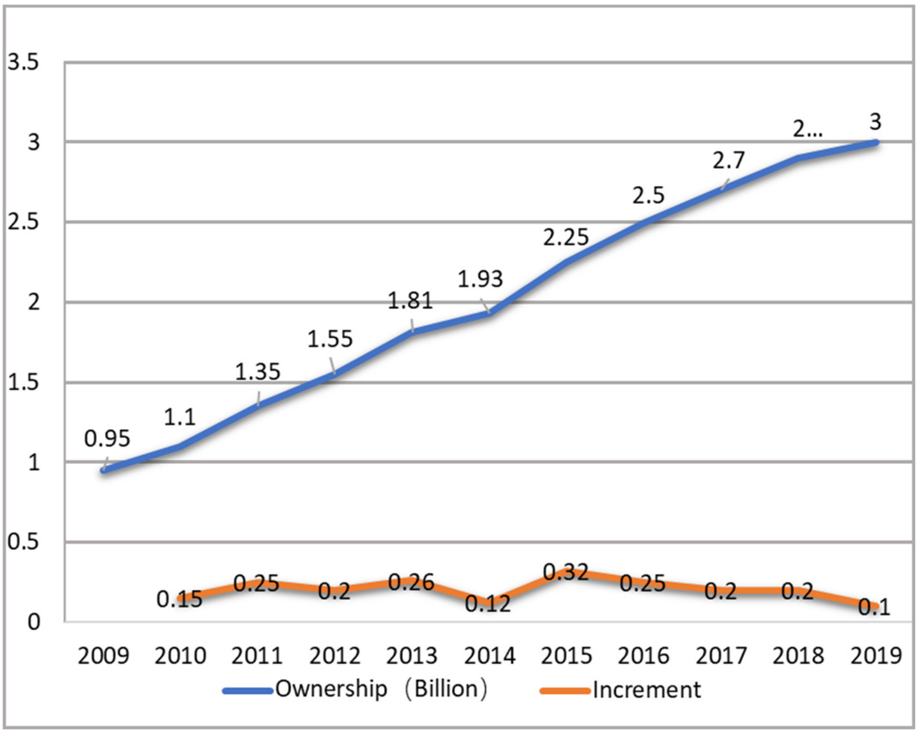

Figure 1. The number of electric vehicles in China from 2009 to 2019
Source: Wind Foresight Industry Research Institute

While electric vehicles have brought great convenience to consumers and enterprises, their charging problems have become increasingly prominent. At present, there are two charging methods: one is to use an ordinary civil electrical socket to charge (socket charging for short), and the other is to use a special charging pile to charge. More than 95% of consumers use household electrical sockets to charge their electric vehicles. Many companies (such as Meituan sales offices) also use ordinary sockets to charge riders' electric vehicles. Socket charging poses a serious safety hazard and causes serious problems. Fire accident. Charging pile charging is a relatively safe charging method, which is not easy to cause serious fire accidents, but there are many disadvantages. First of all, it takes 9 hours for an electric vehicle to fully charge on the charging pile. For users engaged in the food delivery industry, it directly affects the use of the vehicle and the improvement of time efficiency. If an extra battery runs back and forth, it will increase its charging cost and time cost. Secondly, the charging pile charging is carried out outdoors, charging time is long, the management cost is high, often unattended, electric vehicles will also have the risk of theft, and the clustering effect of charging affects the operation of the power grid [1]. Irregular parking and charging during charging has also become a public safety issue in the city. Irregular recycling of replacement batteries will also bring potential environmental pollution hazards.

In order to solve the shortcomings of the two existing charging modes, the charging mode of the switching station came into being. The so-called switching station charging means that the user rides an electric vehicle to a nearby switching station, replaces its lacking battery with a fully charged battery and then leaves, the replaced battery enters a professional charging station for charging, and waits for the next consumer to replace it after being fully charged. use. The power-swap mode adopts safe and energy-saving professional technology to realize the unity of safety and efficiency. It has outstanding advantages and is being favored by many enterprises. Companies such as "e-swap" and "Zhang Fei Travel" build power-swap stations to provide battery-swap services to B-end customers such as "Ele.", "Meituan" and "Dada". Companies such as "Yiqi Power Replacement" and "Yongyou Zhixing" have established power replacement stations to provide general consumers on the C-end with power replacement services. The government strongly supports the implementation of the power swap model in the market. On June 26, 2019, the state-owned enterprise Tower Energy Co., Ltd. reached a cooperative relationship with China Post Express, Yunda Express, Meituan Dianping and other express delivery industries, and began to deploy power swap facilities across the country. Its electric vehicles provide battery swapping services. Two problems need to be solved for the replacement of power stations to be successfully accepted by the citizens and enterprises. One is that the replacement of electricity must have sufficient convenience, and the other is that the cost of replacement of electricity must be low. The more substations built, the greater the density of substations, and the more convenient it is for the citizens to exchange electricity, but the scale of a single substation is also smaller. Due to the economies of scale in the swap station, the larger a single swap station, the lower the cost of serving a single customer. Therefore, there must be a trade-off between the two. At the same time, the distribution of residents in the city is uneven, and the demand for power exchange is also uneven. Planning must be carried out according to the actual situation. Therefore, it is very important to systematically carry out research on site selection for the construction of power exchange stations.

At present, many years of research on site selection by domestic and foreign researchers have achieved many research results and rapid development. The beginning of the site selection problem is the Weber problem proposed by Weber. This problem studies how to minimize the total distance between the warehouse and the customers when a warehouse needs to provide services for multiple customers on a plane. Since then, the issue of facility site selection has received close attention from domestic and foreign researchers, and the site selection research has also become more in-depth. L. Cooper [1] began to expand the Weber problem, considering that the demand is uncertain, with the goal of minimizing the transportation cost, and determining the service point. P. Avella et al. [2] studied the problem of facility location with capacity constraints, and also aimed at the lowest cost, proposed a simple heuristic algorithm to solve the model, and used large-scale examples to verify the effectiveness of the research. .

For the research on the location of charging and swapping stations, scholars mainly study charging stations. The existing research mainly includes two categories: one is the research on the location of charging and swapping stations for specific electric vehicle fleets, including tourist electric sightseeing vehicles, Electric buses, electric logistics vehicles, electric taxis, etc. The second is to study the site selection of charging and swapping stations for tram cars purchased by families. Regarding the site selection of the power station for the tourist electric sightseeing car, Wang[3] first considers the simpler problem of the location of the charging and swapping facilities for the tourist electric sightseeing car, and studies the location of the charging and swapping facilities for the tourist electric sightseeing car in a scenic spot in Taiwan. To optimize the problem, in order to enable tourists to enjoy the entire scenic area smoothly, it is proposed how to establish a mathematical programming model for charging and replacing facilities for electric sightseeing vehicles in the area. Wang et al. [4] used the mixed integer programming method to establish a multi-type charging station location model based on the previous charging background of traveling electric sightseeing vehicles, and on the premise of expanding the coverage of charging stations as much as possible. Regarding the location selection of electric car exchange taxis, Wang et al. [5] analyzed the real data of electric taxis' historical travels, assessed their power exchange demand, and established a power exchange station with the goal of minimizing the total time cost of electric taxi drivers. The site selection optimization model, and finally proposed the layout plan of the electric taxi swap station. In the path planning problem of electric logistics vehicles, Yang Jun et al. [6] considered the construction cost of electric logistics vehicle replacement service facilities and the cost of vehicle transportation, established an integer programming replacement station location model, and designed taboo search-improved Clarke-Wright savings The two-stage heuristic

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algorithm solves the model. M. Schneider et al. [7] considered the carrying capacity of electric logistics vehicles and the hard time window requirements of customers, and established a green vehicle scheduling problem model with time windows and charging stations with the goal of minimizing the distribution path, and proposed a combination The mixed heuristic algorithm of variable neighborhood search algorithm and tabu search algorithm solves the model. M. Schneider et al. [8] considered electric logistics vehicle charging, time window and other factors, and proposed an adaptive variable neighborhood search algorithm to solve the problem of electric vehicle routing with time window and rechargeable. G. Desaulniers et al. [9] put forward the problem of electric vehicle routing with time window in four cases of one charge, multiple charge, partial charge and full charge during the re-distribution process of electric logistics vehicles. M. Keskin et al. [10] proposed a vehicle routing problem with time windows under consideration of the partial and full charging modes of electric logistics vehicles, established a 0-1 mixed integer linear programming model, and developed an adaptive large neighborhood search algorithm to solve the problem. The problem. Yang Lei, Hao Caixia, etc. [11] considered the impact of the time window of electric logistics vehicle users and the time of charging and swapping on route planning and the location decision of charging and swapping facilities, and established the cost of electricity, fixed travel cost of vehicles, opportunity cost and penalty cost. The site selection model for charging and swapping facilities is aimed at minimizing the sum. In the research on the layout planning of electric buses, Wu et al. [12] used the construction cost, operation and maintenance cost of the bus, the cost of power exchange to the charging station, and the power of the charging station in the location planning of the electric bus rapid charging station. A model that minimizes the sum of losses as the goal. The clustering method is used to obtain the preliminary number of charging stations, and then a binary particle swarm optimization algorithm is designed to optimize the stations and determine the capacity. Han Xiao et al. [13] introduced the operation planning method of charging and swapping stations for pure electric vehicles and buses, designed an example based on the operation planning algorithm, and performed simulations for this example. In the research on the site selection of charging and swapping stations for electric cars purchased by families, Yan Bing[14] analyzed the historical power swap demand data of electric car charging and swapping stations, and constructed two kinds of demand for monthly demand data and daily demand data. Forecast model. For monthly demand data, the seasonal autoregressive moving average model is used to predict the demand for charging and swapping. For daily demand data, the exponential smoothing method is used to predict the daily demand to guide the specific operation arrangements of the charging and swapping power station. At present, there is not much research on electric vehicles in China, and most of the researches are still on qualitative aspects. In order to allow more people to use electric vehicles, Yang Mingwei et al. [15] proposed a method to transform the charging shed for electric vehicles.

Based on previous research results, due to the many factors that need to be considered in facility site selection, scholars have different priorities in the research process of facility site selection, so the conditions and methods of various research results are quite different. But there are many lessons to be learned. Site selection problems often involve multiple goals, and these goals are often contradictory, so the multi-objective optimization model of site selection problems has always been an important research direction in the field of site selection research. Similar to the location of electric vehicles, the development of electric vehicle site selection is relatively mature. It not only considers the location of power exchange facilities from multiple angles, but also considers different environments to make the site selection more realistic. Due to the current urban electric vehicle replacement The actual construction of power stations is still based on social demonstrations, and the research on electric vehicles is only qualitative, and there is still a lack of research on electric vehicle replacement stations. Therefore, this

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article has very high theoretical significance and application value for the research on the location of urban electric vehicle land exchange station.

2. Model Building

2.1. Model Assumptions and Symbol Description

(1) The basic assumptions of the model are as follows:

1) Choose the construction site for the replacement station among the many alternatives;

2) A power swap station can provide power swap services to multiple demand points, but a power swap demand point can only go to the nearest power swap station service, and only replace the battery once at a time;

3) The number of substations to be built is within the number of candidate substations, and the substations are mutually independent and parallel, and each substation has a capacity limit;

4) For the battery swapping users, the cost of the swapping distance for the unilateral supplementary power is considered;

5) There is a certain limit on the number of final substations;

6) The distance between the switching station and the demand point is not less than the specified minimum distance;

7) The number of times a battery can be replaced is the total charging time divided by the charging time of a battery;

8) The number of batteries in a swap station must be greater than a certain number to build a swap station;

9) This model only considers the mode of smart switch cabinet;

10) Assuming the same type of battery used by electric vehicle users.

(2) Symbol definition In order to facilitate the definition, the symbols in the model are explained as follows:

2.2. Establishment of Site Selection Model

In this paper, by considering the annual revenue of the switching station operation and the user's annual power exchange distance cost from the demand point to the switching station, this paper solves the problem of selecting the most optimal number and optimal location of the sites from many alternative points, and assigning a corresponding number of sites to each site The problem of replacing the battery. The construction and operation income of the swap station includes two aspects: the annual cost of the initial construction of the swap station, and the operating income during the operation stage. The initial construction cost of the swap station has a great impact on the construction cost recovery period. The operating cost of the swap station is related to the operating profit of the swap station, and the user's replacement cost is directly related to the convenience of the user's replacement.

The location of the electric vehicle swap station is among the candidate locations of the swap station. The location of the swap station is determined based on the constraints of the number of construction stations, the number of batteries in each station, the distance between the station and the distance between the station and the demand point. , To provide customers with the most satisfactory battery exchange service in order to maximize profits. The establishment of a site selection model for electric vehicle swap stations is as follows:

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Table 1. Definitions of model parameters for urban electric vehicle swap station site selection

	SYMBOL	DEFINITION
SET	I	Collection of demand points of electric vehicle users, $\forall_i \in I$
	K	Collection of all candidate swap stations, $\forall_k \in K$
DECISION VARIABLES	y_k	If you build a swap station in a candidate swap station k, then $y_k = 1$, otherwise $y_k = 0$
	T_k	Number of battery swap stations or number of swap cabinets k
PARAMETER	y_{min}	Minimum number of sites to be built
	y_{max}	Maximum number of stations
	B_{ik}	The number of power exchanges from the user demand point i to the candidate switching station k
	C_c	Annual cost of building a site
	x	Service life of substation
	j	Annual interest rate
	b_c	The engineering cost of installing a switch cabinet
	C_w	Annual land acquisition cost
	S	The area of a piece of land
	b_w	The price per unit area of renting a power station land
	b_d	The price of a battery for the replacement station
	v	Battery life
	C_d	Annual cost of purchasing replacement batteries
	b_g	The price of a switch cabinet
	C_n	Annual cost of the initial construction of the substation
	H	Annual operating income
	b_h	The average price of one battery replacement per person
	p	Unit price
	m	Power required for a battery
	C_x	Repair and maintenance cost of substation
	C_y	Operating cost of substation
	C_h	The user's power exchange cost from the demand point to the exchange station
	λ	Electric vehicles consume electricity per kilometer
	d_{ik}	The distance from the demand point i of the power swap user to the candidate swap station k
	t_k	Number of power exchanges k
	r	Charging time of a battery
	σ_{ik}	If the distance between the user demand point i and the switching station k is the shortest,then $\sigma_{ik} = 1$, otherwise $\sigma_{ik} = 0$
	ω	Minimum value of battery in replacement station

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$$\max C_y = 365 b_h \sum_i \sum_k B_{ik} - (365 p \sum_i \sum_k m B_{ik} + 1\% \sum_k b_c y_k + 2\% \sum_k T_k y_k) -$$

$$[\frac{j(1+j)^x}{(1+j)^x - 1} \sum_k (b_c + b_g) y_k + \sum_k b_w S y_k + \frac{j(1+j)^v}{(1+j)^v - 1} \sum_k b_d T_k y_k] \quad k \in K \tag{1}$$

$$\min C_h = \sum_i \sum_k d_{ik} B_{ik} \sigma_{ik} y_k \tag{2}$$

$$\text{s.t. } \sigma_{ik} = \begin{cases} 1 & \text{if } \mathrm{d_{ik}} = \mathrm{min} \, \mathrm{d}_{ik} \\ 0 & \text{otherwise} \end{cases} \quad \forall_k \in K, \quad \forall_i \in I \tag{3}$$

$$\sum_{k \in K} \sigma_{ik} y_{\mathrm{k}} = 1 \quad \forall_i \in I \tag{4}$$

$$y_{\min} \le \sum_{k \in K} y_k \le y_{\max} \tag{5}$$

$$B_{ik} \ge 24 \omega y_k / r \tag{6}$$

$$T_k \ge 0 \quad \forall_k \in K, \forall_i \in I \tag{7}$$

$$y_{\mathrm{k}} = 0,1 \quad \forall_k \in K \tag{8}$$

Number of site batteries:

$$t_k = \sum_{i \in I} \sum_{k \in K} B_{ik} \sigma_{ik} y_k \tag{9}$$

$$\mathrm{t}_k = 24/\mathrm{r} \times \mathrm{T}_k \tag{10}$$

In the model established above:

The formula (1) is the objective function to maximize the annual operating income of the construction operator. In the objective function, the first term is the annual operating income; the second term is the annual cost of purchasing electricity from the power supply company; the third term The annual cost of repair and maintenance for the replacement station. The fourth item is the initial annual cost of station construction (engineering cost); the fifth item is the annual cost of purchasing replacement batteries; the sixth item is the annual land acquisition cost, and the seventh item is the annual cost of software and hardware investment and research and development;

The formula (2) is the objective function, which minimizes the annual cost of battery replacement for electric vehicle users on the way of battery replacement;

The formula (3) is to define a 0-1 matrix, which restricts each demand point to the nearest switching station for power exchange;

The formula (4) restricts each demand point to only one switching station to serve it;

The formula (5) is the restriction on the number of substations;

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The formula (6) is to ensure the service level of the swap station, restricting that only when the total number of swaps exceeds a certain value, the swap station can be established in the candidate swap station, otherwise it is not allowed;

The formula (7) is a non-negative constraint of variables;

The formula (8) is the 0-1 constraint on whether the candidate substation is to be constructed or not;

The formula (9) defines the number of times that the battery can be replaced in the replacement station;

Equation (10) defines the number of batteries in the replacement station.

3. Algorithm Design

In this study, the site selection and battery distribution of the stations are taken as a whole, combined with the ideas and principles of the genetic algorithm, and a genetic algorithm suitable for solving this model is constructed. Algorithm design includes six tasks, including chromosome encoding and decoding, generating initial population, fitness function design, genetic operators, constraint processing methods, termination conditions, etc.

(1) Encoding and decoding

This research adopts binary coding method. First, use consecutive integers to assign an ID number to each candidate switching station. For example, if there are 6 candidate switching stations, then ID numbers 1 to 6 respectively represent a candidate switching station. Then perform coding. The length of the coded bit string is 6, the number of candidate substations, then the coded bit string {1, 1, 0, 0, 0, 1} indicates that the candidate substation with ID number 1, 2, 6 is Selected.

(2) Generate the initial population

The size of the initial population has a direct impact on the convergence of the algorithm. If the size is too large, the calculation time will increase and the efficiency will be low; when the size is too small, it is easy to cause the algorithm to mature prematurely and reduce the diversity of the population. Choose between. In this paper, the chromosomes in the initial population are randomly generated, and the number of genes in the initial population must meet the constraints.

(3) Fitness function design

Since the fitness value is the only deterministic index for the selection of individual survival opportunities in a group, the form of the fitness function directly determines the evolutionary behavior of the group. In order to directly associate the fitness function with the number of populations in the population, the fitness value is specified as non-negative in the genetic algorithm, and in any case, the larger the better, the site selection of urban electric vehicle replacement stations is established Multi-objective function, formula (1) seeks to maximize the annual operating income of the construction operator, formula (2) seeks to minimize the user's power exchange distance, use the weight coefficient change method to set the objective function, and assign the formula according to the actual situation (1) Weight, assign weight to formula (2), where this method is used in this article to establish the following fitness function:

$$g(y,T)=\alpha f(y,T)+\beta\sum_i\sum_k d_{ik}B_{ik}\sigma_{ik}y_k$$

$$f(y,T)=365b_h\sum_i\sum_k B_{ik}-(365p\sum_i\sum_k mB_{ik}+1\%\sum_k b_c y_k+2\%\sum_k T_k y_k)-$$

$$[\frac{j(1+j)^x}{(1+j)^x-1}\sum_k(b_c+b_g)y_k+\sum_k b_w S y_k+\frac{j(1+j)^v}{(1+j)^v-1}\sum_k b_d T_k y_k]$$

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$f(y,T)$ is the objective function (1)

For example, if the weight is 0.4, 0.6, and the initial population size is 10, then 10 coded bit strings, namely chromosomes, are randomly generated. Assuming that the coded bit string {1, 1, 1, 0, 0, 0} is one of them, calculate The fitness value process is as follows:

1) Coded bit string {1, 1, 1, 0, 0, 0} means $y_1 = 1$, $y_2 = 1$, $y_3 = 1$, $y_4 = 0$, $y_5 = 0$, $y_6 = 0$ Substitute into the above formula;

2) In the same way, find the values of all 10 initial chromosomes.

(4) Genetic operator

The operation operator of genetic algorithm usually includes three basic forms of selection, crossover and mutation, which constitute the core of genetic algorithm with powerful search capabilities.

1) Selection: The roulette method is used to select individuals in this article. The roulette method is also called the proportional selection method. The fitness of each chromosome determines its probability of being selected, that is, the greater the fitness, the greater the probability of being selected.

The specific calculation method is as follows:

a. Calculate the fitness of each chromosome $g(x = 1,2,\ldots,n)$, n is the size of the population;

b. Calculate the probability of each chromosome being selected;

$$P(x) = \frac{g(x)}{\sum_{x=1}^{n} g(x)}$$

c. Calculate the cumulative probability of each chromosome;

$$s(x) = \sum_{x=1}^{n} P(x)$$

d. Generate a uniformly distributed pseudo-random number r in the interval $[0,1]$;

e. If $r < s[1]$, then select individual 1, otherwise k, select individual such that: $q[k-1] < r \le q[k]$ holds;

f. Repeat d and e a total of n times.

In order to ensure that individuals with the best adaptability are retained in the next-generation population as much as possible, this method can also achieve the effect of accelerating convergence.

2) Crossover: The crossover operator of the genetic algorithm is to imitate the gene recombination process of sexual reproduction in nature. Its function is to inherit the original good genes to the next generation of individuals and generate new individuals with more complex gene structures. If the crossover probability is too small, it will not only cause the evolution speed to be too slow, but also stop the search; the mutation probability will be too large, which will make the search tend to be randomized. Therefore, in this article, the single-point crossover method is used for crossover operation, and the crossover probability is set as p_c, and the value range is $0.1 \sim 0.9$, and the specific execution process is as follows:

a. Select two pairs of individuals in the group according to the roulette method.

b. For each pair of individuals that are paired with each other, set the crossover point according to the crossover probability, and exchange the chromosomes after the crossover point of the two individuals, thereby generating two new individuals.

The schematic diagram of the single point crossing is as follows:

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$$\begin{array}{l} A:1\,1\,1\,1\,0\,0\,0\,1\,\vdots\,1\,0 \\ B:1\,1\,1\,1\,0\,1\,0\,1\,\vdots\,0\,0 \end{array} \xrightarrow{\text{Single point crossover}} \begin{array}{l} A':1\,1\,1\,1\,0\,0\,0\,1\,\vdots\,0\,0 \\ B':1\,1\,1\,1\,0\,1\,0\,1\,\vdots\,1\,0 \end{array}$$

3) Mutation: In the process of mutation, if the mutation probability is too large, it will increase the probability of damage to the original good genes; but if it is too small, it will lead to a decrease in the ability to produce new individuals and premature setting. In this paper, the basic bit mutation method is used, and the mutation probability is set as p_m, and the value range is set as $0.01 \sim 0.1$. The specific implementation process is:

a. Perform mutation operations on the two chromosomes after cross-recombination according to the mutation probability;

b. For each designated mutation point, perform the inverse operation on its gene value to replace it, thereby generating a new individual.

$$A:1\,1\,1\,1\,0\,\boxed{0}\,0\,1\,0\,0 \xrightarrow{\text{Mutations}} A':1\,1\,1\,1\,0\,\boxed{1}\,0\,1\,0\,0$$

(5) Constraint processing method

Because there are many constraints in the mathematical model corresponding to the location of electric vehicle swap stations, the infeasible solutions in the adopted coding method account for a large proportion of the population. This article uses the following two methods to limit the constraints.

a. Limit the search space. Regarding the constraint of the number of substations, the maximum value of 1 is always in the limited area.

b. Regarding the limitation of the number of batteries in the switching station, the selective crossover mutation operation is continuously performed on the chromosomes produced until a satisfactory result is obtained.

(6) Termination conditions

The termination condition is generally to set the iterative algebra, and there is also a method that the fitness reaches saturation, and the continued evolution will not produce an approximate solution with better fitness. This article sets the maximum number of iterations according to the iteration situation, and the value range is $200 \sim 3000$.

4. Case Analysis

In order to verify the correctness of the algorithm, Tianwen Street and Changshengqiao Street, Nan'an District, Chongqing, which are densely populated, were used to switch power stations. Demand points and candidate nodes are shown in Figure 2, which contains 305 demand points and 20 candidate points.

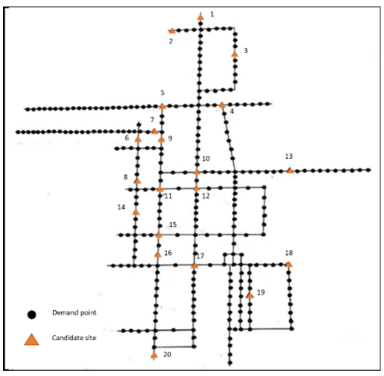

Figure 2. Demand sites and candidate sites

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According to market research, the following basic data are obtained:

Table 2. Basic Data Sheet

The service life of the switch cabinet	6 years
Annual interest rate	3%
Replacement cabinet installation engineering fee	10000 yuan/piece
Lease a piece of land with an area	10 square meters
Unit price of leased land	50 yuan/square meter
The price of a battery	2000 yuan
Battery life	3 years
The price of a switch cabinet	20000 yuan
The average price of one-time replacement	10 yuan
The power required for a battery	1 kWh
Unit electricity price	0.658 yuan/kWh
Electric vehicles consume electricity per kilometer	0.147 kWh/km
One battery charging time	2 hours
Minimum value of battery in replacement station	10

According to the genetic algorithm designed to solve the urban electric vehicle swap station sites, and the number of batteries allocated to each site. Suppose the population size is 80, the number of iterations is 500, the crossover probability is 0.8, the mutation probability is 0.1, the weight is set α=1, β=-50 , and the solution is solved by python software programming. The site selection results are as follows:

Table 3. Site selection results

number	Whether to build	number	Whether to build
1	0	11	0
2	0	12	1
3	1	13	0
4	0	14	0
5	0	15	0
6	0	16	1
7	1	17	0
8	0	18	0
9	1	19	0
10	0	20	1

Note: In the table, 0 means no construction, 1 means construction.

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Table 4. Number of batteries allocated at the site

Site number	Number of batteries allocated
3	4
7	18
9	19
12	10
16	22
20	4

5. Conclusion

The optimal solution to the above problems is obtained through genetic algorithm, and the urban electric vehicle swap station site and the number of electric vehicles equipped at each site that maximize the annual operating income of the construction operator and minimize the user's power replacement cost are obtained. This method not only considers The needs of tram users can improve the convenience of users to replace electricity, reduce costs for construction operators, avoid waste of resources, and provide an important reference for the planning of urban electric vehicle replacement stations.

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