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Multiobjective Optimization Method of Location and Capacity Determination Problems of Highway Charging Stations*

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Abstract: [**Purposes**]The location and capacity determination of highway charging stations are of great significance for the application and promotion of electric vehicles. [**Methods**] Aiming at the problem of capacity selection and location of highway charging stations, the average adaptation rate of charging stations, that is, the degree of matching between the charging demand of electric vehicles and the current total capacity of charging stations, is introduced. A new multi-objective optimization model is established with objectives of minimizing the construction cost of charging stations and maximizing the average adaptation rate of charging stations. [**Findings**]The multi-objective optimization model is tested by the NSGA-II algorithm, and the validity of the model is verified. In addition, it further studies the impact of the number of travelling vehicles, the power of the charging pile, and the cruising range on the construction cost and adaptation rate of the charging station. [**Conclusions**] The results of numerical experiments show that: the multi-objective optimization method proposed in this paper can get higher utilization rate and lower construction cost of charging station, which provides a more scientific and reasonable reference for the problem of location and capacity determination of charging station.

Keywords: multi-objective optimization model; location and capacity determination of charging stations; construction cost; the average adaptation rate; NSGA-II algorithm

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With the change of technology, new energy vehicles have received more and more attention from the whole society. Compared with hybrid vehicles, pure electric vehicles are more in line with people's economic and environmental concept of life. However, due to the limitation of battery technology, today's electric vehicles still not enough for long-distance driving, which makes electric vehicles not fully accepted. Therefore, the research on the optimal location and capacity determination of the charging station is of great significance to overcome the shortcomings of the electric vehicle with too short endurance mileage, reduce the construction cost of the charging station, improve the utilization rate of the charging station, and realize the reasonable allocation of resources.

At present, the research on the location and capacity determination of charging stations mainly focuses on the location and capacity determination of electric vehicle charging stations in cities. Lam et al. [1] proved that the planning problem of EV charging station is NP hard. Four solutions were proposed and their effects in various simulation examples and practical applications are evaluated. Zhu et al. [2] aimed at minimizing the total cost of travel from the charging station to the destination of the traveler and minimizing the construction cost of the charging station, proposed an optimization model for the location of electric vehicle charging stations in the city, and designed algorithm for solving the model based on the gene Algorithm. Luo et al. [3] considered the charging system composed of a variety of charging facilities and proposed a new optimization model to minimize

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the annual social cost of the entire EV charging system. It is transformed into mixed integer second-order cone programming, and the urban bus route is calculated as an example. In view of the fact that drivers may detour due to traffic jams and other situations, Yang et al.[4] put forward a closure location model based on service radius, aiming at the maximum sum of temporary demand and fixed demand user flow. The internal roads of the city are relatively dense, and the driving distance of vehicles is relatively short. The above model can not describe the location of charging station on the intercity expressway well.

At present, most of the charging stations have been built in urban areas, a small number of them are distributed on highways. When electric vehicles travel in medium and long distance, they will face the problem of insufficient endurance and difficult charging. Chung et al.[5] established a multi-cycle optimization model based on the flow-refueling site selection model for charging station site planning, and conducted a case study based on the actual traffic flow data of the Korean highway network in 2011. However, the paper only studies a single road and does not consider complex road networks. Li et al.[6] established a multi-cycle and multi-path charging station location model based on the extended road network to dynamically meet the travel demand generated by the increase in the number of electric vehicles. Ghamami et al.[7] proposed a general model for a single highway to determine the optimal location and capacity of the charging station, and used a meta-heuristic algorithm to solve the model. Shao et al.[8] proposed the utility function of charging station capacity and deviation distance, and reasonably allocated multiple charging demands based on logit model. Considering the constraints of charging station queuing time and electric vehicle mileage, and aiming at maximizing the total utility of users, a charging station location model in competitive environment is established. Wang et al.[9] Based on the utility theory, the driver's charging strategy is analyzed. According to the driver assignment rules of each charging station, a mixed integer programming model is established to solve the problem. Lim et al.[10] studied the site selection of energy supplement stations of new energy vehicles, such as hydrogen, ethanol, electric power, etc., and proposed three heuristic algorithms to adapt to different characteristics of the model, and verifies the effectiveness of these algorithms in complex problems. The above models are all single objective optimization models. The location and capacity of the charging station need to consider the construction cost, the scope of the station's influence, the number of vehicles that can be served, the resource utilization rate, and the profit rate. It is essentially a multi-objective optimization problem.

In recent years, multi-objective optimization models have been widely used in the fields of investment portfolio, resource management, environmental protection, engineering construction, and transportation. Meng et al.[11] established a multi-objective optimization model for highway ramp metering. Wang et al.[12] established a multi-objective optimization model with the goal of maximizing cumulative attraction and minimizing cumulative distance for the location problem, and proposed an effective algorithm. Marcenaro-Gutierrez et al.[13] studied the satisfaction of labor market workers by establishing a multi-objective optimization model, and provided a decision reference for labor market management. Xidonas et al.[14] established a new multi-objective optimization model for portfolio problems by incorporating future returns into the current investment decision-making process. However, at present, few studies use multi-objective optimization model to study the location and capacity determination problems of highway charging stations.

Note that the model proposed in reference [6] only considered the location of charging stations, and considered the capacity of each charging station to be infinite. However, there are important differences in terms of construction cost, charging station utilization, number of serviceable vehicles, and vehicle queuing time for different capacity charging stations. Therefore, when planning the charging station, the location and capacity of the charging station should be considered at the same time. When determining the total service of each charging station, this article analyzes whether the vehicle enters the charging station or not, and how much the battery is charged according to the remaining mileage of the vehicle at the charging station. Considering that when determining the capacity of the charging station, it should correspond as much as possible to the total amount of services currently required. Excessive construction of the charging station will lead to waste of resources, and insufficient capacity of the charging station will also lead to congestion of the charging station. This paper proposes the capacity adaptation degree of the charging station and regards it as one of the optimization goals. Based on the reference [6], this paper aims at minimizing the construction cost of charging stations and maximizing the capacity adaptability of charging stations. A multi-objective optimization model of charging station location and capacity setting based on the remaining vehicle mileage is established. The model was solved by using the NSGA-II algorithm. At the same time, the influence of vehicle range, charging pile power and vehicle number on the model results is also studied in this paper.

1 Question raise

The road network is composed of multiple cities, multiple connected highways and some charging stations deployed in them. The electric vehicle starts from one city and passes through the highway to another city. If endurance mileage of the electric vehicle is less than the total travel distance, it needs to enter a charging station for charging during the journey, and then continue driving. It is possible that this charging process will be repeated many times, and finally the electric vehicle will arrive at the destination city. During this time, electric vehicles will face several decision issues:

1) Path selection. There are often multiple routes from one city to another. First of all, the actual route should be selected from multiple routes.

2) Charging station selection. There are multiple charging stations on a certain section of highway. In order to successfully complete the journey, you need to choose the charging station that will enter.

3) Charging charge selection. When the vehicle enters the charging station, the amount of charging will be selected based on the current remaining power and the distance to the next charging station.

In order to simplify the problem, this paper makes the following assumptions about the location and capacity of the charging station planning:

1) Electric vehicles will choose the shortest path between the two places when planning their routes. If the shortest path does not have a suitable charging station for electric vehicles, the construction scheme of the charging station is not feasible.

2) When there are multiple charging stations in a certain path, the vehicle will select the farthest charging station within the remaining mileage in order to reduce the charging times as much as possible. For example, if the path of the vehicle is $\{o, s_1, \cdots, s_i, s_j, \cdots, s_n, d\}$, and the charging station that can be reached from the starting point under the range limit is $\{s_1, s_2, s_3\}$, the vehicle v will choose s_3 to charge for the first time. Then start from s_3 and repeat the previous process until all the charging stations $\{s_3, \cdots, s_j\}$ selected to enter are found.

3) When the electric vehicle is charged in the fast charging station on the highway, the charging efficiency of the first 90% of the electric quantity can be regarded as linear. In order to protect the battery during the last 10% of the charging, the power of the charger will be greatly reduced and the charging time will be greatly increased. Therefore, it is assumed that in order to save time, the owner will choose to charge 90% of the full power. But there is a special situation. If the distance to the next charging station or the destination is greater than 90% of the vehicle's cruising range, the owner will choose to fully charge the electric vehicle. Therefore, the mileage supplemented at the charging station can be described as

$$l_i^v = \begin{cases} 0.9v^c - B_i^v, D_{i,j} \leqslant 0.9v^c \\ v^c - B_i^v, 0.9v^c \leqslant D_{i,j} \leqslant v^c \end{cases}. \tag{1}$$

Consider that the charging rate of the charging pile in the fast charging stage is λ, and the charging rate in the stable charging stage is $\frac{1}{3}\lambda$. The charging time of an electric vehicle at a charging station can be described as

$$t_i^v=\begin{cases}\dfrac{l_i^v}{\lambda},D_{i,j}\leqslant 0.9v^c\\ \dfrac{l_i^v-0.1v^c}{\lambda}+\dfrac{0.1v^c}{\dfrac{1}{3}\lambda},0.9v^c\leqslant D_{i,j}\leqslant v^c\end{cases}. \tag{2}$$

Fig. 1 is a simple schematic diagram of a road network. Point A is the starting city, point B and point C are the destination city, S1, S2, S3 and S4 are the charging stations available along the way, and the endurance mileage of electric vehicles is assumed to be 200 km. When the electric vehicle starts from A to B with full power, it will go through three charging stations, with a total distance of 220 km, so it can not be directly reached. According to the above assumption, it will select charging station S2 for charging, charge 100 km of power, and then directly arrive at point B. If the electric vehicle goes from A to C, it will choose to charge at S4. In this way, the construction of charging stations in S1 and S3 is overbuilding with a utilization rate of 0.

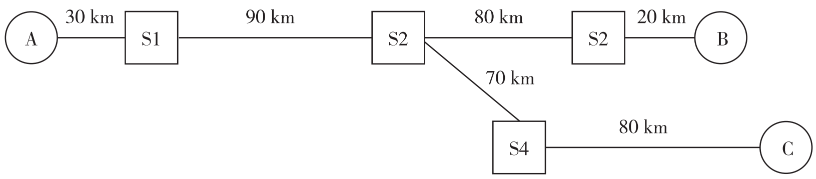

Fig. 1 Schematic diagram of the location of charging stations in a simple road network

The existing electric vehicle endurance mileage will be greatly affected by temperature, speed, driving habits, road congestion and other factors. And the power consumption of different models of vehicles driving the same distance may be different. Therefore, in order to simplify the problem, the following assumptions are proposed:

1) The influence of external environment such as temperature on vehicle endurance is not considered.

2) Only the endurance mileage of the electric vehicle is considered, and the charged electricity is regarded as the increased endurance mileage. And the different energy consumption of each vehicle is not considered. When each vehicle runs the same distance, the endurance mileage consumed is equal to the driving distance, regardless of vehicle differences.

3) Regardless of road congestion, it is assumed that all vehicles are running at a constant speed, and the driving mileage reduction caused by frequent start and stop of electric vehicles in congestion is not considered.

4) Assume that all vehicles are fully charged at the time of departure.

According to the above assumption, for electric vehicle v, according to the driving path, the location of the charging station can be obtained as $\{s_i,s_j,\cdots\}$, the charge amount in each charging station is $\{l_i^v,l_j^v,\cdots\}$, and the charge time required in each charging station is $\{t_i^v,t_j^v,\cdots\}$. The total charging time of charging station is $\sum_{v\in V}t_i^v$. Considering that there are α_i charging piles and a single charging pile can work 24 hours, the utilization rate of a single charging station can be expressed as

$$F(\alpha_i)=\frac{\sum_{v\in V}t_i^v}{24\alpha_i}Z_i. \tag{3}$$

For efficient utilization of resources, the closer $F(\alpha_i)$ is to 1, the better. The average adaptation rate of all charging stations can be expressed as

$$f_2=1-\frac{\sum_{i\in\widetilde{N}}(F(\alpha_i)-1)^2Z_i}{\sum_{i\in\widetilde{N}}Z_i}. \tag{4}$$

2 Model establishment

According to the above analysis, this paper establishes the following multi-objective optimization model for the location and capacity determination of expressway charging station:

$$\min f_1 = \sum_{i \in \tilde{N}} W_i (C^b + \alpha_i C^c) Z_i, \tag{5}$$

$$\max f_2 = 1 - \frac{\sum_{i \in \tilde{N}} (F(\alpha_i) - 1)^2 Z_i}{\sum_{i \in \tilde{N}} Z_i}. \tag{6}$$

$$\text{s. t. } D_{i,j} \leqslant \beta_0, \tag{7}$$

$$B_i^v + l_i^v = D_{i,j} + B_j^v, \forall i, j \in \tilde{N}, \tag{8}$$

$$B_r^v = v^c, \forall r \in R, R \subseteq N, \tag{9}$$

$$B_i^v \geqslant 0, \forall i \in \tilde{N}, \tag{10}$$

$$Z_i \in \{0, 1\}, \forall i \in \tilde{N}, \tag{11}$$

$$\alpha_i \in \mathbf{N}, \forall i \in \tilde{N}. \tag{12}$$

W_i: node weight coefficient, $i \in \tilde{N}$.

C^b: fixed cost for construction of charging station.

C^c: deployment cost of single charger in charging station.

α_i: number of chargers at the charging station at the node i, integer variable, $\alpha_i \in Z, i \in \mathbf{N}$.

Z_i: 0-1 variable, whether to build a charging station at the node i, if yes, it is 1, if not, it is 0.

λ: a single charging pile can supplement endurance mileage per hour.

l_i^v: vehicle v supplementary endurance mileage at charging station i.

$D_{i,j}$: distance from charging station i to charging station j.

β_0: the maximum distance between two adjacent charging stations.

R: set of starting city nodes.

v^c: maximum range of the vehicle v.

B_i^v: the remaining mileage of the vehicle v at the node i.

N: set of city nodes.

$\tilde{N}$: set of alternative points of charging station.

$\mathbf{N}$: set of natural numbers.

Different locations of charging stations will have different land costs, and there will be fixed costs due to the construction of some infrastructure during construction. And there will also be uncertain costs depending on the capacity of the charging station. The first objective function of the model is to minimize the cost of charging station construction. Too many chargers in the charging station will cause a large number of chargers to be idle. Too few chargers may not meet the actual needs. Therefore, the second objective function of the model is to maximize the average adaptation rate of the charging station.

Constraint (7) is to make the distance between adjacent charging stations in the same path less than a certain value; Constraint (8) is the cruising range balance constraint. The remaining cruising range of vehicle v at node i plus the cruising range supplemented at node i is equal to the distance from node i to node j plus the remaining endurance mileage of vehicle v at node j. Constraint (9) requires the vehicle v to be fully charged at the starting point. Constraint (10) requires that the vehicle's remaining power at any node is not less than 0.

3 Solution algorithms

The planning of expressway charging station is a NP hard problem. At present, most of the problems are solved by evolutionary algorithm, see [15-18]. NSGA-II proposed in reference [19] is one of the excellent algorithms to solve the multi-objective optimization model. In this paper, NSGA-II algorithm is used to solve the above multi-objective optimization model. Because the variables in the model include the 0-1 variable Z_i of whether to build a charging station and the number of chargers that each charging station needs to assemble, that is, the capacity α_i of the charging station, which are all integer variables. Therefore, the form of the solution is considered to be $x=(\underbrace{1,0,0,\cdots,0,1}_{n},\underbrace{26,12,\cdots,34}_{n})$, where n is the number of charging station candidate sites. Convert the solution to binary encoding $x=(1,0,0,\cdots,0,1,\underbrace{0,1,1,0,1,0},\underbrace{0,0,1,1,0,0},\cdots,\underbrace{1,0,0,0,1,0})$. The length of the binary code varies according to the upper limit of the charging station's capacity. If the length is k and the number of candidate sites is n, then the total chromosome length is $n+nk$. The specific algorithm steps are as follows:

Step 1: Generate the initial population randomly according to the population number N_{pop}, check whether each chromosome meets the constraints, and delete the unsatisfied chromosome.

Step 2: The objective functions f_1 and f_2 are calculated for each chromosome, and $\{f_1^{(1)},f_1^{(2)},\cdots,f_1^{(N_{\text{pop}})}\}$ and $\{f_2^{(1)},f_2^{(2)},\cdots,f_2^{(N_{\text{pop}})}\}$ are obtained. According to the value of the objective function, k ranking levels $\{s_1,s_2,\cdots,s_k\}$ are obtained by fast non dominated ranking, and the probability of the i-th level being selected is $P(s_i)=\dfrac{(k+1-i)^2}{\sum\limits_{i=1}^{k}i^2}$.

Step 3: According to the level selection probability $P(s_i)$, two levels s_i and s_j are selected by roulette algorithm, and then a chromosome is randomly selected from them. The two chromosomes are encoded, crossed and mutated to generate new chromosomes. Decode the new chromosome and detect its feasibility. If the restriction is not satisfied, discard the chromosome. Combine the parent population and the child population, if the number of population reaches $2N_{\text{pop}}$, go to step 4, otherwise repeat step 3.

Step 4: The combined population is sorted by fast non dominated algorithm, and the whole population with lower level is put into the next generation parent population. If the s_i layer cannot be completely put into the next generation parent population, then the crowding degree is calculated for the s_i layer chromosomes, and the chromosomes are put into the next generation population in descending order according to the crowding degree, until the number of the next generation population reaches N_{pop}.

Step 5: If the number of iterations is less than the set maximum number of iterations $G_{\max}$, go to step 2, otherwise the algorithm will be terminated.

4 Solution algorithms

Consider the test network diagram shown in Fig. 1, which has 10 city nodes connected by highways. All highways are bidirectional and can be regarded as the same distance. Tab. 1 shows the node distance of the test network and the shortest distance between nodes can be abtained by Floyd algorithm, as shown in Tab. 2. The alternative points for the construction of charging stations are evenly distributed on each connected edge at intervals of 30 km.

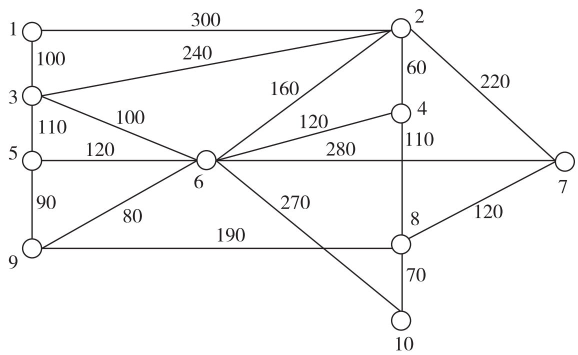

Fig. 2 Schematic diagram of the road network structure

Tab. 1　The distance between city nodes in the network

	City1	City2	City3	City4	City5	City6	City7	City8	City9	City10
City1	0	300	100							
City2	300	0	240	60		160	220			
City3	100	240	0		110	100				
City4		60		0		120		110		
City5			110		0	120			90	
City6		160	100	120	120	0	280		80	230
City7		220				280	0	120		
City8				110			120	0	190	70
City9					90	80		190	0	
City10						230		70		0

Tab. 2　The shortest path distance between city nodes in the network

	City1	City2	City3	City4	City5	City6	City7	City8	City9	City10
City1	0	300	100	320	210	200	480	430	280	430
City2	300	0	240	60	280	160	220	170	240	240
City3	100	240	0	220	110	100	380	330	180	330
City4	320	60	220	0	240	120	230	110	200	180
City5	210	280	110	240	0	120	400	280	90	350
City6	200	160	100	120	120	0	280	230	80	230
City7	480	220	380	230	400	280	0	120	310	190
City8	430	170	330	110	280	230	120	0	190	70
City9	280	240	180	200	90	80	310	190	0	260
City10	430	240	330	180	350	230	190	70	260	0

Assume that the maximum range of electric vehicles is 200 km and 300 km，each accounting for 50％ of the total. Firstly，the travel data of vehicles in the test network is generated. It is assumed that all electric vehicles start from one city and reach the destination city through expressway. At the same time，in order to study the impact of the number of vehicles on the planning of charging stations，10 000，50 000 and 100 000 electric vehicles are randomly generated as the starting and destination cities. Tab. 3 shows the 50 000 vehicle trip data generated by the simulation.

Tab. 3　Travel data of electric vehicles

Origin city	Destination city									
	1	2	3	4	5	6	7	8	9	10
1	0	526	880	340	472	222	209	342	159	108
2	572	0	2 951	1 744	439	379	1 077	157	888	812
3	321	197	0	326	1 193	233	1 064	320	243	149
4	283	1 421	208	0	915	633	486	522	287	333
5	672	468	163	497	0	147	201	1 102	844	343
6	1 278	295	1 460	1 180	704	0	385	245	496	742
7	179	225	138	642	752	279	0	1 113	169	740
8	230	404	288	700	523	271	148	0	119	566
9	256	301	536	247	549	784	1 645	515	0	505
10	193	273	309	181	289	548	1 597	324	811	0

The weight coefficients of the charging station of the city node and the charging station on the highway are both taken as 1. It is assumed that a single charging pile can supplement 200 km/h. Assuming that β_0, the maximum distance between adjacent charging stations, is 180 km, the fixed cost of charging station construction is 1 million yuan, and the deployment cost of single charger is taken as 30 thousand yuan. The maximum endurance mileage of vehicles is assumed to be 200 km and 350 km, each accounting for half of the total number of vehicles. We use NSGA-II algorithm to solve the above multi-objective problem and the results are shown in Fig. 3 and Fig. 4. Tab. 4 shows the specific construction plan comesponding to one of the solutions.

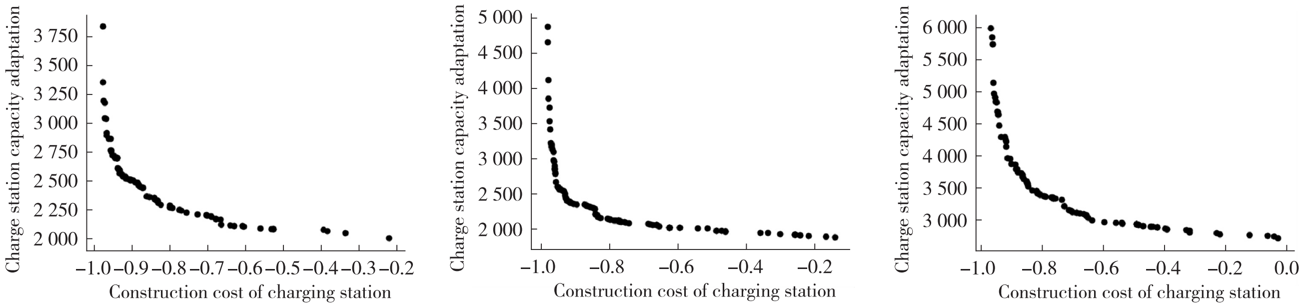

Fig. 3 Pareto front of the model with different number of vehicles

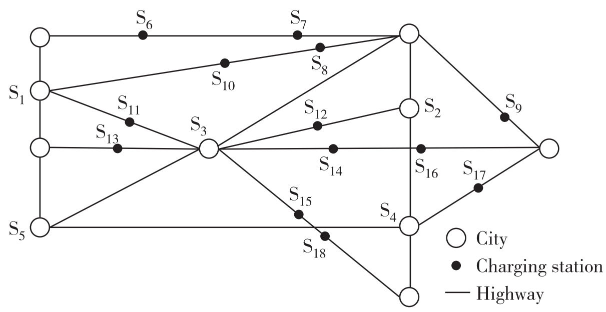

Fig. 4 Charging station planning for 50 000 electric vehicles

Tab. 4 NSGA-II solution

Charging station	Charging piles	Charging station	Charging piles
s_1	27	s_{10}	2
s_2	24	s_{11}	33
s_3	47	s_{12}	45
s_4	49	s_{13}	21
s_5	19	s_{14}	45
s_6	3	s_{15}	19
s_7	4	s_{16}	16
s_8	16	s_{17}	42
s_9	19	s_{18}	16

Fig. 3 is the Pareto front of the model when the number of traveling vehicles is 10 000, 50 000, and 100 000, respectively. It can be seen that this algorithm can obtain a good Pareto solution when solving the multi-objective optimization model established in this article, and is not affected by the number of traveling vehicles. With the increase of travel vehicles, the construction cost of the charging station has increased significantly, and the matching degree of the charging station capacity has also increased, and the difference in the degree of adaptation between the various schemes has been reduced to a certain extent. This is because the available service volume of a single charging station increases with the increase of traffic flow, and the gap between the numerator and denominator in (2) becomes smaller, so the adaptation rate increases. Set the vehicle's endurance mileage as 200 km, the number of vehicles as 50 000, the hourly supplementary mileage of charging piles as 100, 300 and 400 km respectively, and the Pareto front of the model is shown in Fig. 5.

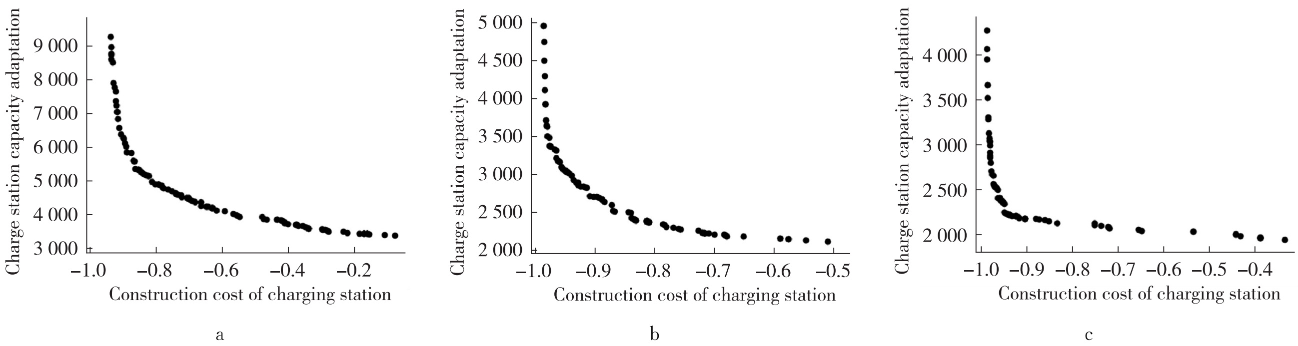

Fig. 5　Pareto front of the model with different power of charge point.

Fig. 5 shows that with the increase of the power of charging piles, the number of charging piles deployed in each charging station has decreased significantly, and the construction cost of charging station has also decreased significantly. In addition, when the construction cost is 60 million yuan, 30 million yuan and 25 million yuan, the cost reduction will cause a substantial drop in the charging station adaptation rate. When choosing a construction plan, try to avoid those lower-cost plans.

Keep the additional endurance mileage of charging pile per hour as 200 km, 50000 vehicles for travel, and the vehicle's endurance mileage is 100, 200, 300 and 400 km respectively, and the Pareto front of the model is shown in Fig. 6.

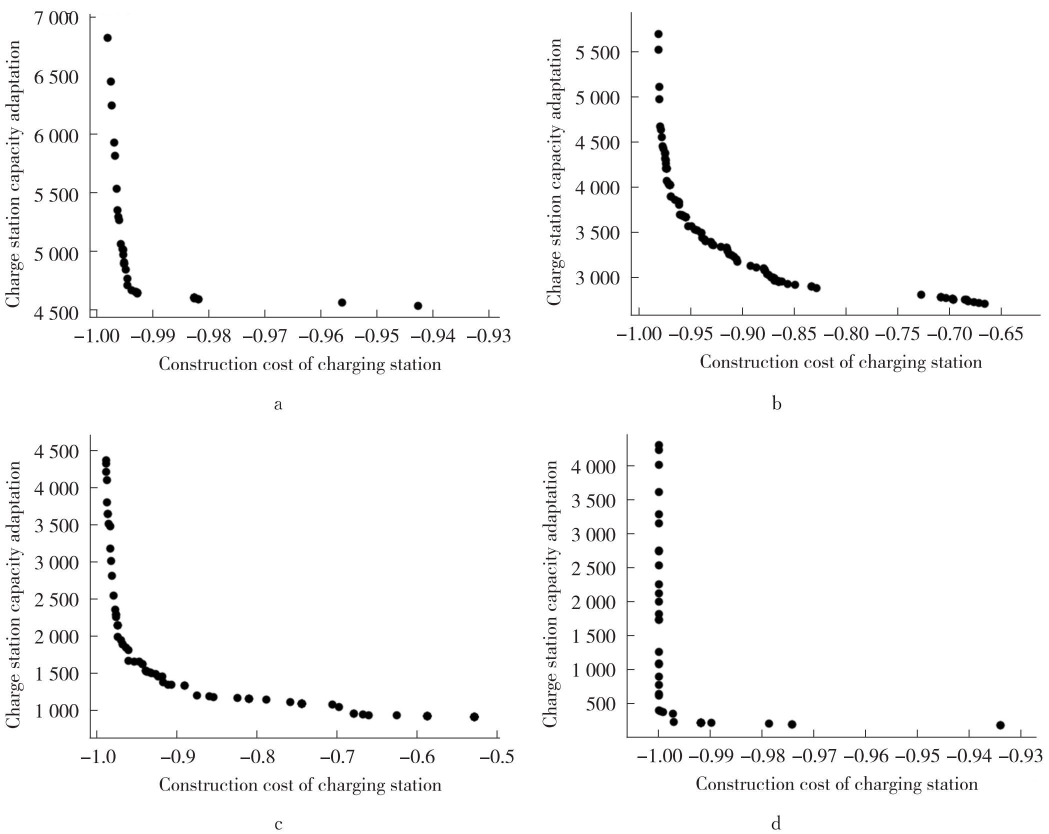

Fig. 6　Pareto front of the model with different endurance mileage

Fig. 6 shows that with the increase of the cruising range of electric vehicles, the construction cost of charging stations has been significantly reduced, and the average adaptation rate of charging stations has not changed significantly. This also shows that our method is effective, and it can get good Pareto solutions in many calculations. Especially when the vehicle endurance mileage is 100 km and 400 km, the charging station adaptability of each planning scheme is mostly concentrated above 99%. This is because the number of potential construction schemes is small at this time, and the algorithm performs better on small-scale problems. Figures 5 and 6 show that changes in the power of the charging pile and the cruising range of the electric vehicle will have a significant impact on the construction cost of the charging station. Increasing the fast charging rate of the charging pile and increasing endurance mileage of the electric vehicle have a significant effect on reducing the total cost.

It will be seen that all three factors mentioned above have a significant impact on the solution of the model. Therefore, the decision-makers should fully investigate these three factors and get accurate data when planning the highway charging station. Only in this way can we scientifically plan and build the highway charging station.

5 Conclusions

This paper studies the location and capacity of the charging station of the expressway. From the perspective of the remaining endurance mileage of electric vehicles, we analyze the behavior of the owner of the charging vehicle to select the charging station and charge the electricity, and a multi-objective optimization model with the goal of minimizing the construction cost of the charging station and maximizing the average adaptation rate of the charging station is established. After that, the NSGA-II algorithm was used to carry out numerical experiments on the model to verify the rationality and effectiveness of the model. In addition, this article further analyzes some relationships between the construction cost of the charging station and the adaptation rate of the charging station capacity with endurance mileage of the electric vehicle and the power of the charging pile. The research methods proposed in this paper can provide a more scientific decision-making reference for the optimal planning of charging stations.

There are still some key problems to be solved in the study of charging station planning: 1) the mathematical model established for the location and capacity of charging station is generally a non convex and non-linear mixed integer programming problem. How to design a more efficient solution algorithm according to the specific structural characteristics of the model is one of the core problems to be solved; 2) how to reconstruct the location and capacity model of the charging station to achieve the global and efficient solution of the model is also a key problem to be further studied; 3) at present, the existing research on the location and capacity problem of the expressway charging station mainly focuses on the numerical experiment of the small-scale problem, and how to propose a new mathematical model for the large-scale location and capacity problem developing efficient algorithm is the key problem to be further studied.

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运筹学与控制论

高速公路充电站选址定容问题的多目标优化方法

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摘要：【目的】高速公路充电站位置选择和容量确定对电动汽车应用推广具有重要意义。【方法】针对高速公路充电站选址定容问题，通过引入充电站的平均适配率，即电动汽车的充电需求与当前充电站总容量之间的匹配程度，以充电站的建设成本最小和充电站的平均适配率最大为目标建立了新的多目标优化模型。【结果】利用多目标优化问题的 NSGA-II 算法对模型进行了数值实验，验证了模型的有效性。此外，本文也进一步研究了出行车辆数量、充电桩功率以及续航里程对充电站的建设成本和适配率的影响。【结论】数值实验表明：本文提出的多目标优化方法可以得到更高的充电站利用率和更低的建设成本，为高速公路充电站的选址定容问题提供了更加科学合理的决策参考。

关键词：多目标优化模型；充电站的选址定容；建设成本；平均适配率；NSGA-II 算法

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