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Location of Electric Vehicle Charging Station based on ArcGIS

Jing Wang

College of Transport and Communications, Shanghai Maritime Univ., Shanghai 201306, China

*Email: 201930610013@stu.shmtu.edu.cn

Abstract

With the rapid economic and social development of our country, the number of private cars has also increased rapidly, and at the same time, the problems of noise pollution and environmental pollution have become more and more prominent. As a kind of new energy vehicle, electric vehicle has quickly entered people's field of vision with its advantages of no pollution, low noise, convenient use and high energy utilization efficiency. However, wide-spread and universal adoption of electric vehicles requires a well-established infrastructure for electric vehicles, namely a network of charging facilities. Nowadays, there are still problems such as unreasonable location selection and unsound network in the setting of charging stations. It is urgent to analyze the current road network and build a reasonable charging station selection model. With the help of geographic information system, this paper analyzes and integrates the traffic hot spots and road network in Lingang area of Shanghai, and constructs a charging station site selection model with the help of charging station accessibility and charging station construction cost. The model composition is determined, and reference opinions are provided for the site selection and construction of the charging station.

Keywords

Electric Vehicle; Charging Station; Dijkstra Algorithm; ArcGIS.

1. Introduction

With the rapid growth of Chinese economy, the demand for energy is also increasing. China's economic development in recent years has led to a large waste of energy and rapid deterioration of the environment. Environmental and energy issues have become one of the most concerned issues in China and the international community.

Since the beginning of the 20th century, the automobile industry has developed rapidly. The development of the traditional automobile industry is inseparable from the consumption of a large number of oil resources, which brings the shortage of resources and the problem of environmental pollution year by year. In order to avoid this situation, it is imperative to reduce the dependence of the automobile industry on mineral resources.

In this case, new energy vehicles came into being. New energy vehicle refers to the vehicle that uses unconventional vehicle fuel as the power source (or uses conventional vehicle fuel and adopts new on-board power device), integrates the advanced technology of vehicle power control and drive, and forms an advanced technical principle, new technology and new structure.

Broadly speaking, new energy vehicles include pure electric vehicles, fuel cell electric vehicles, which all use non petroleum fuels, as well as hybrid electric vehicles, ethanol gasoline vehicles and other vehicles that use non petroleum fuels. It can be divided into the following categories: hybrid vehicles, pure electric vehicles, fuel cell vehicles, alcohol ether fuel vehicles, natural gas vehicles, etc. Among them, pure electric vehicles themselves basically do not emit pollutants harmful to the

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environment. Activities such as saving electricity can be concentrated in specific areas such as power plants, which can achieve centralized emission and centralized treatment and minimize the impact on the environment. As a secondary energy, electric energy can be easily converted from a variety of primary energy. With the development of technology, the continuous improvement of energy conversion technology and the continuous acceleration of the development of electric vehicles, it is becoming an important part of the development of new energy vehicles.

Although the use of battery can greatly simplify the vehicle structure and reduce the occurrence of faults, the continuity of electric vehicles is poor because the existing battery power storage technology still needs to be developed. While promoting the development of technology, the setting of charging station provides a feasible solution for the application of electric vehicles under the current situation. Nowadays, the construction of charging stations and other supporting facilities in China is still in its infancy. This paper discusses the location of charging stations with the help of ArcGIS, so as to provide a feasible reference scheme for the construction of charging stations in China in the future.

The first chapter of this paper introduces the development of new energy vehicles and the advantages and disadvantages of electric vehicles in China, and briefly describes the research content, research purpose and research methods of this paper. The second chapter analyzes the general methods of solving the location problem, and makes assumptions about the relevant data involved in this model. In the third and fourth chapters of this paper, the rationality index model of charging station location is established and solved by Dijkstra algorithm. The rationality indexes of charging station construction when building one and two charging stations are obtained respectively. The fifth chapter analyzes and discusses the results of modeling and solution, summarizes the areas to be improved in the process of model establishment, and puts forward improvement suggestions for the later research.

2. Problem Analysis and Data Preparation

2.1 Location Problem

Location problem is one of the classic problems in operational research. The location problem is widely used in production and life, logistics and even military, such as the location of factories, warehouses, first aid centers, fire stations, waste treatment centers, logistics centers, missile warehouses and so on. Location is one of the most important long-term decisions. The quality of location directly affects the service mode, service quality, service efficiency and service cost, thus affecting the profit and market competitiveness, and even determining the fate of enterprises. Good site selection will bring convenience to people's life, reduce costs, expand profits and market share, and improve service efficiency and competitiveness. Poor site selection will often bring great inconvenience, loss and even disaster. Therefore, the research on site selection is of great economic, social and military significance.

The location problem includes many classical problems, such as Weber problem, median problem, coverage problem, central problem, multi-objective location, competitive location, unpopular facility location, location allocation, location route. The location problem of electric vehicle charging station can be solved by establishing a discrete location model.

2.2 Study Area

This paper downloads the road network data of Shanghai from the open source map service website OpenStreetMap, and uses ArcGIS software to intercept the road network data near Lingang New Area. The research area is south of dazhihe Road, outside the Shanghai Ring Expressway, and east of the new Siping highway, as shown in the figure. It is considered to study ten sub regions in this area, and the geographical distribution is shown in the figure.

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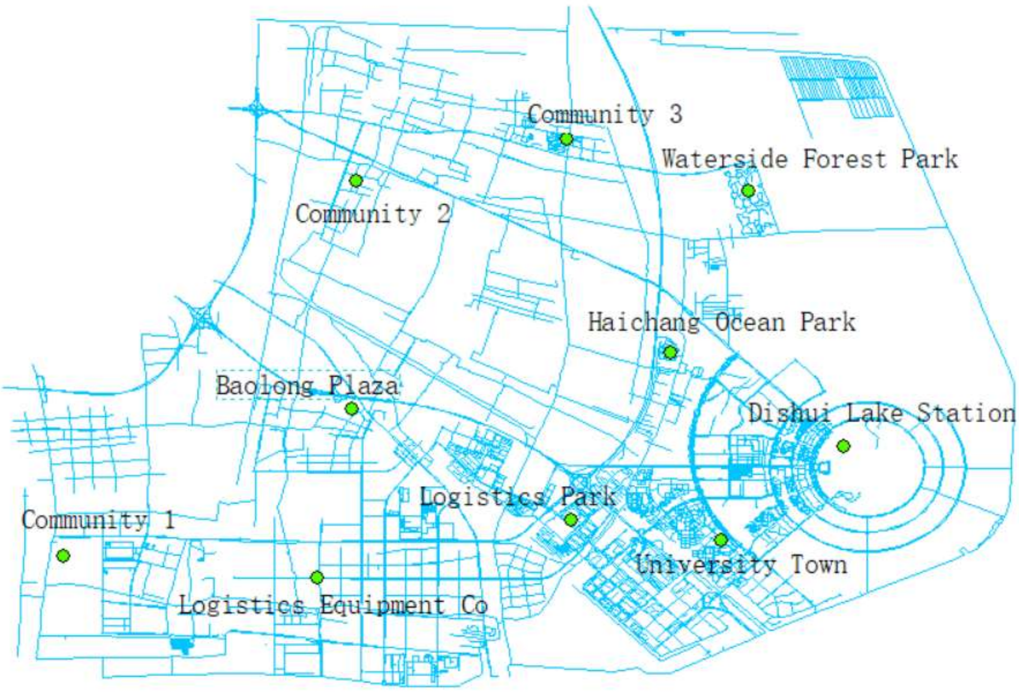

Fig. 1 the study area and the spot position

This study assumes that all regions have the same status, and uses ArcGIS for ranging to obtain the following simplified traffic network with 10 nodes and 14 sides (distance unit of each node: km).

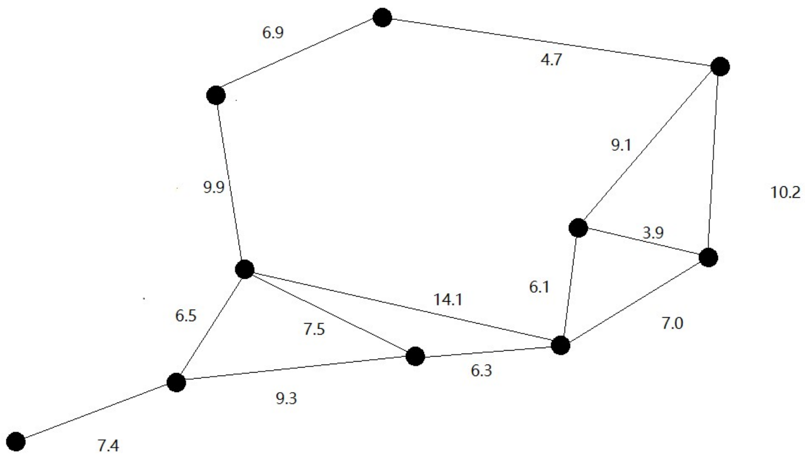

Fig. 2 the distance data in the net work

2.3 Selecting Principle

As a service facility, the rationality of charging station location mainly depends on the realization of service functions. After literature research, this paper believes that the charging station should have the following characteristics in the process of location selection, and the construction address has good accessibility, so that users in more areas can reach it smoothly; The cost in all aspects of the construction process should be low. Since the normal operation of the charging station requires a lot of financial support, the excessive construction cost will bring unnecessary economic pressure and waste of resources; The construction area shall have a good physical and geographical environment and social environment, and comply with the construction planning of relevant areas.

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3. Model Establishment

Due to the limited relevant data, this paper plans to select several areas from the 10 areas for the construction of charging stations, and select the construction scheme according to the rationality of the construction of charging stations.

3.1 Model Assumptions

(1) The construction and rationality of charging station are related to its accessibility and construction cost.

(2) The accessibility of charging station I depends on the shortest distance and D from each area to the area where charging station I is located_ I represents.

(3) The tendency of charging station users in each region to use the charging station is only affected by its accessibility.

(4) The construction cost of the charging station is C.

3.2 Formulation

The rationality P of charging station location is calculated according to the following formula:

$$p = \omega_1 \sum_{i=1}^{n} d_i + \omega_2 \bullet nc \tag{1}$$

Where:

ω_1 is the proportion of regional accessibility in rationality.

ω_2 is the proportion of charging station construction cost in rationality.

n is the number of charging stations.

4. Shortest Distance Calculation based on Dijkstra Algorithm

4.1 Dijkstra Algorithm

Dijkstra algorithm is a typical single source shortest path algorithm, which is used to calculate the shortest path from one node to all other nodes. The main feature is to take the starting point as the center and expand outward layer by layer until it reaches the end point.

Dijkstra's algorithm is often used in data structure, graph theory, operations research, etc. The problem of the calculation process is described as: Based on the undirected graph $G = (V, E)$, it is assumed that the length of each edge $E[i]$ is $w[i]$ to find the shortest path from vertex $V0$ to the rest of the points.

4.2 Algorithm Ideas and Steps

Divide the vertex set V in the weighted undirected graph G=(V, E) into two groups, the first group is the point set S for which the shortest path has been found, and the second group is the point set U for which the shortest path has not been found. Add the vertices of the second group to S in order of increasing length of the shortest path. In the process of joining, always keep the shortest path length from the source point v to each vertex in S no greater than the shortest path length from the source point v to any vertex in U. In addition, each vertex corresponds to a distance, the distance of the vertex in S is the shortest path length from v to this vertex, the distance of the vertex in U is the current from v to this vertex including only the vertex in S as the middle vertex Shortest path length.

a. Initially, S only contains the source point, that is, S={v}, and the distance of v is 0. U contains other vertices except v, that is: U={rest vertices}, if v has an edge with vertex u in U, then <u,v> has normal weight, if u is not the outgoing edge adjacent point of v, then The weight of <u,v> is ∞.

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b. Select a vertex k with the smallest distance v from U, and add k to S (the selected distance is the shortest path length from v to k).

c. Taking k as the newly considered intermediate point, modify the distance of each vertex in U; if the distance from the source point v to the vertex u (passing the vertex k) is shorter than the original distance (doing not pass the vertex k), then modify the distance of the vertex u The distance value, the distance of the vertex k of the modified distance value plus the weight on the edge.

d. Repeat steps b and c until all vertices are contained in S.

4.3 Example Calculation

In order to facilitate the analysis, the ten regional residential communities 1, CIMC Yangshan logistics equipment company, Lingang Baolong square, Lingang Poulos international logistics park, Lingang University City, Shanghai Haichang Ocean Park, Shanghai Metro Dishuihu station, Shanghai Binhai Forest Park and residential communities 2 and 3 selected in this paper are numbered as study areas 1-10, and the connection matrix shown below is obtained.

Table 1. the connection matrix of the spots

Area	1	2	3	4	5	6	7	8	9	10
1	0	7.4	0	0	0	0	0	0	0	0
2	7.4	0	6.5	9.3	0	0	0	0	0	0
3	0	6.5	0	7.5	14.1	0	0	0	0	9.9
4	0	9.3	7.5	0	6.3	0	0	0	0	0
5	0	0	14.1	6.3	0	6.1	7	0	0	0
6	0	0	0	0	6.1	0	3.9	9.1	0	0
7	0	0	0	0	7	3.9	0	10.2	0	0
8	0	0	0	0	0	9.1	10.2	0	4.7	0
9	0	0	0	0	0	0	0	4.7	0	6.9
10	0	0	9.9	0	0	0	0	0	6.9	0

Import the connection matrix into the program for calculation to obtain the shortest path calculation result as shown in the figure. The value of each item in the list represents the previous point in the shortest path to the corresponding point.

```
[0, 0, 1, 1, 3, 4, 4, 5, 7, 8]
[1, 0, 1, 1, 3, 4, 4, 5, 7, 8]
[1, 2, 1, 2, 3, 4, 4, 5, 7, 8]
[1, 3, 3, 2, 3, 4, 4, 5, 7, 8]
[1, 3, 3, 4, 3, 4, 4, 5, 7, 8]
[1, 3, 3, 4, 5, 4, 5, 5, 7, 8]
[1, 3, 3, 4, 5, 6, 5, 6, 7, 8]
[1, 2, 9, 4, 5, 7, 7, 6, 7, 8]
[1, 2, 9, 2, 5, 7, 7, 8, 7, 8]
[1, 2, 9, 2, 3, 7, 7, 8, 9, 8]
```

Fig. 3 the shortest pathin the transportation network

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Table 2. the shortest length between the spots

Area	1	2	3	4	5	6	7	8	9	10
1	0	7.4	13.9	16.7	23	29.1	33	43.2	47.9	54.8
2	7.4	0	6.5	9.3	15.6	21.7	25.6	35.8	40.5	47.4
3	13.9	6.5	0	7.5	13.8	19.9	23.8	34	38.7	45.6
4	16.7	9.3	7.5	0	6.3	12.4	16.3	26.5	31.2	38.1
5	23	15.6	13.8	6.3	0	6.1	10	20.2	24.9	31.8
6	29.1	21.7	19.9	12.4	6.1	0	3.9	14.1	18.8	25.7
7	33	25.6	23.8	16.3	10	3.9	0	10.2	14.9	21.8
8	43.2	35.8	34	26.5	20.2	14.1	10.2	0	4.7	11.6
9	47.9	40.5	38.7	31.2	24.9	18.8	14.9	4.7	0	6.9
10	54.8	47.4	45.6	38.1	31.8	25.7	21.8	11.6	6.9	0

According to the shortest path matrix as shown in the figure, the shortest path matrix of each point is obtained, as shown in the table.

4.3.1 Construction of a Charging Station

When there is only one charging station, the shortest distance from each area to other areas and the accessibility of the area can be expressed. Therefore, the sum of the corresponding shortest distances of each area can be calculated, and the calculation results are shown in the table below. It can be seen that under the condition of building a charging station, area 5 and area 6 have the smallest and shortest distance, that is, building the charging station in Lingang university city or Shanghai Haichang Ocean Park has the best accessibility.

Table 3. the situation for one station

Area number	1	2	3	4	5	6	7	8	9	10
Dmin(km)	269	209.8	203.7	164.3	151.7	151.7	159.5	200.3	228.5	283.7

The rationality of charging station construction is calculated as follows:

$$p_1 = 151.7\omega_1 + \omega_2 c \tag{2}$$

4.3.2 Construction of Two Charging Stations

In the case of building two charging stations, the shortest distance from each area to the charging station should select the smaller value of the distance between the two charging stations. The calculation of this problem is discussed exhaustively through the programming method, and the shortest distance value corresponding to the combination of each area is calculated as shown in the table below.

Table 4. the situation for two stations

Pair	Dmin	Pair	Dmin	Pair	Dmin	Pair	Dmin	Pair	Dmin
(1,2)	202.4	(2,3)	190.7	(3,5)	119.7	(4,8)	78.7	(6,8)	109.4
(1,2)	202.4	(2,3)	190.7	(3,5)	119.7	(4,8)	78.7	(6,8)	109.4
(1,3)	189.8	(2,4)	144.7	(3,6)	96.5	(4,9)	78.7	(6,9)	104.7
(1,4)	145.7	(2,5)	113.2	(3,7)	88.7	(4,10)	87	(6,10)	111.6
(1,5)	120.5	(2,6)	91.8	(3,8)	82.3	(5,6)	121.2	(7,8)	128.9
(1,6)	102.3	(2,7)	84	(3,9)	87	(5,7)	109.5	(7,9)	124.2
(1,7)	98.4	(2,8)	79.4	(3,10)	101.9	(5,8)	91.1	(7,10)	129.7
(1,8)	98.8	(2,9)	84.1	(4,5)	126.5	(5,9)	86.4	(8,9)	190.9
(1,9)	106.3	(2,10)	100.8	(4,6)	102.1	(5,10)	93.3	(8,10)	188.7
(1,10)	127	(3,4)	151.2	(4,7)	90.6	(6,7)	136.1	(9,10)	221.6

After sorting and screening, it can be seen that in the case of building two charging stations, the minimum distance sum corresponding to point pairs (4,8), (4,9) is 78.7km, and one charging station can be selected from the combination of Lingang Poulos international logistics park and Shanghai Binhai Forest Park, Lingang Poulos International Logistics Park and residential community 2, which has the best accessibility.

The rationality of charging station construction is calculated as follows:

$$p_1 = 78.7\omega_1 + 2\omega_2 c \tag{3}$$

5. Conclusion

5.1 Result Analysis

In this paper, according to Dijkstra algorithm, the shortest path to the charging station in each area is calculated to represent the accessibility, and the accessibility and the construction cost of the charging station are used to represent the rationality of the location of the charging station. The rationality indexes of Building 1 and 2 charging stations are calculated respectively.

Although the consumption level of residents in Lingang New Area varies greatly, and the residents who can afford electric vehicle consumption, charging and other services are affected by the regional distribution, considering that with the development of the pilot Free Trade Zone, the development of Lingang is also gradually accelerating, and the development prospect of electric vehicles in this area is good, the construction scheme of building two charging stations is still selected. It is conceivable that the initial construction cost is high, and it is difficult to achieve immediate results due to residents' consumption level, but the good accessibility of the two charging station schemes will enhance the willingness of nearby residents to use pure electric vehicles. The promotion and use of pure electric vehicles will not only improve the quality of life of nearby residents, but also play a positive role in promoting the development of Lingang New Area.

5.2 Deficiencies and Prospects

5.2.1 Insufficient Data Preparation

Due to the lack of relevant literature research, relevant data on the construction cost of charging station can not be consulted, and the rationality index of charging station construction can not be converted into accurate data to guide production practice. The travel survey workload of residents in the area is too large and difficult to achieve, resulting in inaccurate analysis of residents' travel intention, and the division of research areas needs to be improved.

Since it is impossible to calculate the distance between each point on the map and the matching road, it can only be assumed that a charging station can be built at the center of a certain area, which is inconsistent with the actual situation.

5.2.2 Research Prospect

This paper discusses the location of electric vehicle charging station by establishing the rationality index of charging station location, and obtains some constructive conclusions combined with specific examples. However, due to the lack of data research and other aspects, there is still a lot of room for optimization. In future research, the travel intention of residents can be investigated and counted by means of questionnaire survey, so as to improve the action coefficient between the three factors; Through literature research, various influencing factors such as the scale of charging station, charging time and cost, and the natural and social environment of the construction area are added to the index; Through the learning of GIS software, the distance in the region is calculated, so as to establish the continuity model.

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