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Electric Vehicle Development Planning System Based on AHP and BASS Model

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Abstract With the increasingly serious challenges of energy and environment, each country applies them to boost the electric vehicle industry. The global automobile industry has entered a new stage of development of the power revolution; it definitely that construct charging station is the core element during this process. This article is going to discuss the reasonable development plan of electric vehicle according to the analytic hierarchy process (AHP) and BASS model.

1. Introduction

With the development of social economy, energy shortage, environmental pollution and other problems have been became obviously serious; there are massive disadvantages in terms of traditional gasoline cars and diesel cars while the electric cars do not. Meanwhile, the development of charging station is the core restriction element of the electric car market. The development of electric vehicles is becoming more and more important.

2. Model Establishment and Solution

2.1 The number of model
(1)Model establishment
Assume each charging station will be established same equipment quality and Layout

n :the quality of charging pile of each charging station

T :the average charging time per vehicle

w :the average working time of each charging pile

N_{charge} :the percentage of average daily charging vehicles by station

Therefore the required charging station number N_{charge} is derived as follows:

$$N_{charge} = \frac{kwT}{nt}$$

(1)

Where k is the number of EVs covered by the charging station and is determined by the number and usage of EVs.

$$k = \frac{2dq_1 N}{q\omega}$$

(2)

Where the $2d$ is stands for the average kilometer of the electric vehicle, q_l is equals to the consumption of electric per a hundred kilometer, N represents the battery capacity of the vehicle, q represents Battery capacity of electric vehicles ω means the discharge depth is determined by SOC.

(2)Parameter determination

Under the relative references and resources, we assume the battery is keeping the best situation in U.S, customers would like select the maximum discharge depth of battery is 80%, and the average driving course is 180 kilometer. Through probabilistic method, we can conduct the average charging frequency of vehicle is P_c.

$$P_c = \sum_{0}^{L=n} R_L P_L$$

(3)

Where L represents the customer travel distances, R_L represents the percentage of users to different travel distances, P_L represents the probability of charging for different travel distances. We find the average probability of charging is 25 per cent by American resources, so we assume half of users are going to accept the charging pile as the first option. The total number of car ownership in the United States in 2017 was 245,803,350 vehicles. The other parameters take the median of the EV performance parameters. At the same time, it is assumed that the number of charging posts per charging station is eight.

2.2 distribution model

We should consider the inventory of electric vehicles towards the city, rural areas and suburban areas, because this is the most direct component that decides to build charging stations or not. Assume the ratio of urban cars to total cars is equal to α_{city} ,suburban and rural areas is α_{sub} and α_{rural} respectively.

Then according to the formula (1)(2)find：

The number of charging stations in the city is

$$N_{c-c} = \frac{2dq_l N \cdot \alpha_{city} \cdot wT}{nqwt} \cdot r_{city}$$

(4)

The number of suburban charging stations is

$$N_{c-s} = \frac{2dq_l N \cdot \alpha_{sub} \cdot wT}{nqwt} \cdot r_{sub}$$

(5)

The number of rural charging stations is

$$N_{c-r} = \frac{2dq_l N \cdot \alpha_{rural} \cdot wT}{nqwt} \cdot r_{rural}$$

(6)

Where α_{city} , α_{sub} , α_{rural} are correction factors, its value is related to the various road condition, government subsidies, gasoline, charging price. Moreover, the inventory of electric vehicles is urban area (68%), suburban area (22%) and rural area (10%). Assume correction factor is 1.05, 0.9, and 0.89 respectively,The city needs to build 2 million 960 thousand cities to build charging stations, 820 thousand in the suburbs and 370 thousand in rural construction, such as Figure 1 below.
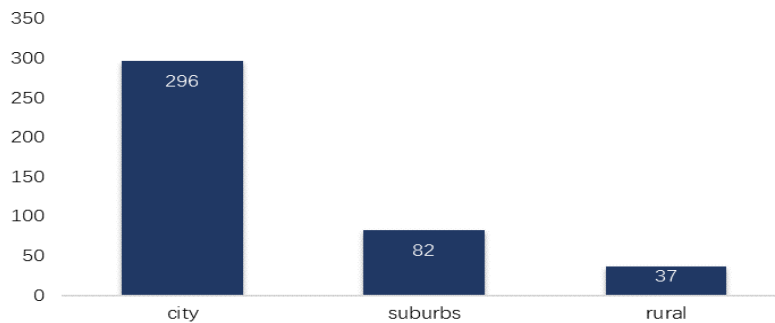
figure 1 The United States to build the number of charging stations Column chart（Unit: million)

2.2.1 Korea electric car and charging station development plan
As the Table 1, we use the South Korea, Ireland and Uruguay as samples to discuss problems around electric vehicle development. To be specific, we accept per GDP, position, population and other elements to analysis the issue indeed.

table 1South Korea, Ireland and Uruguay part of the national information

Nation	Per capita GDP （USD）	Location	Population (million)	National Land area （Sqkm）	Population density （person/Sq km）
Uruguay	15221	South America	344	176215	18.65
South Korea	27538	Asia	5125	100210	525.7
Ireland	61606	Western Europe	477	70273	69.3

Through the comparison, not only is South Korea's population density and amount much larger than that of Uruguay and Ireland, but also this country has strong nuclear energy system that solves a huge amount of consumption of electric. In the meantime, it is important that the government of Korea has realized the blueprint of electric vehicle, and also planned "10 year development plan" is aimed to progress the industry of electric vehicle in 10/2009.Obvisouly, the government of Korean has paid enough attention on this industry, thus we choose the Korea as research object.

2.3 charging station number distribution and location of the issue
(1) South Korea, the number and distribution of charging stations
According to the figure from KNSO, the inventories of vehicles are 22 million across the country until 2017. The urban, suburban, rural area is occupied by 91%, 5%, 4% respectively. From the equation (1),(2),(3),(4),(5),(6) and keep other parameters same, the Korea is required building 50, 0000 charging stations totally where the urban area should establish 455000 stations and 25000 stations for suburban area, others belong to the rural area.

(2) Korea charging station location site model
We also need to ensure the specific position except the quantity of charging stations and placement. As we know, the purpose of building charging station networks are absorbing more people to purchase electric vehicles, and it will be convenient for existing users. Furthermore, we conduct the optimal model includes reducing the cost of using and constructing as well.

$$\min C = \sum_{j=1}^{m} \beta_j p_j [(u - x_j)^2 + (v - y_j)^2]^{\frac{1}{2}}$$

$$\min S = \sum_{x=1}^{m} \sum_{y=1}^{m} S_{xy} r_{xy} \qquad (7)$$

$$s.t. \begin{cases} \sum_{j=1}^{m} p_j \leq Q \leq S_q \text{ (Restrictions1)} \\ x_{\min} \leq x_j \leq x_{\max} \text{ (Restrictions2)} \\ y_{\min} \leq y_j \leq y_{\max} \text{ (Restrictions3)} \\ x_{\min} \leq u \leq x_{\max} \text{ (Restrictions4)} \\ y_{\min} \leq v \leq y_{\max} \text{ (Restrictions5)} \\ \sum_{x=1}^{m} \sum_{y=1}^{m} r_{xy} = M \text{ (Restrictions6)} \end{cases}$$

In the formula，C:Where,: the user charges the whole process of charging;

p_j: Need user's charging demand j;

(u,v) ：The location coordinates of the filling station to be requested;

(x_j, y_j) ：Known location coordinates of the requesting user j;

β_j ：Unit distance, the unit charge coefficient;

m ：The number of users in the planning area;

Q : Filling station daily average power supply;

S_{xy} ：The cost of building a charging station;

M :The number of building charging stations;

$r_{xy} = \begin{cases} 1, & \text{Build a charging station in (x,y)} \\ 0, & \text{Do not build a charging station in (x,y)} \end{cases}$

The restriction 1 is stands for the users who accepted daily charging service cannot above mean value of supply, then it has not below the requirement amount. The restriction 2 to 5 means the condition of restriction zone. The restriction 6 represents whole limitation of constructing stations.

(3) The key factors affecting the development plan of electric vehicles

Electric vehicles itself, whether its performance indicators can reduce the charging time, reduce the number of charging and prolong the time of endurance.

The convenience of charging, which means the construction and planning of the charging power station are suitable or not.The expense of charging or the cost of using electric vehicles, it includes cost of money and timing;The government policies, subsidies, loans and so on;Advertisement could influence the development plan of electric vehicle.Environmental aspects, zero emissions (pure electric vehicles use electric energy, no exhaust emission in driving, no pollution of the environment).

2.4 Electric Vehicle Ownership Prediction Model Based on Bass Model
(1) Bass Model

Bass model is widely used in various industries in the development of new product diffusion forecast, because of its comprehensive consideration, the advantages of internal and external factors, the electric car from scratch, Bass model to forecast the ownership property may be taken. By using

the analogy method to estimate the parameters, if we assume that when the electric vehicle is t then the inventory of vehicle is equal to:

$$N(t) = mF(t) = m\frac{1-e^{-(p+q)t}}{1-\dfrac{q}{p}e^{-(p+q)t}} \qquad (8)$$

The historical data of traditional automobile can be used to calculate the relevant parameters due to similar development path of traditional automobile and electric vehicle,. Where m is the market potential maximum number of users, p is the external factor coefficient; q represents the internal factor.

From Figure 2 Traditional car External factors influence coefficient Zero emission.
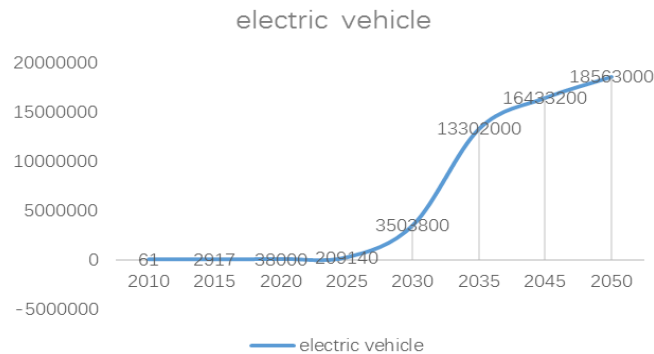

Figure 2 the fitting curve of traditional vehicle parameter estimation

From Figure 2 Traditional car External factors influence relatively coefficie $P_{tradition}$=0.83

Influence coefficient of traditional automobileinternal factors $P_{tradition}$=0.42.

The external factors that affect the electric vehicle market are mainly government subsidies to electric vehicles, environment of building charging facilities, environmental impact, advertising and so on. On the other hand, the price of electric vehicles, electric vehicle mileage and electric vehicle market recognition would be the core factor from the internal side. Using the Delphi method, the external factors adjustment factor is represented by $\beta_p = \dfrac{5}{3}$, and internal factor adjustment coefficient is $\beta_q = \dfrac{7}{11}$, so internal and external factors influence coefficient for electric vehicle is:

$$p = \beta_p \bullet p_{tradition} = 0.005$$
$$q = \beta_q \bullet q_{tradition} = 0.267$$

Assume that the largest potential user of the market M is 25 million .

(2) Charging station siting principle (center principle)

The of demand electric vehicle charging, technology development, operation model, charging station construction target, service radius, city planning, city road network planning, development policy and technical specification documents, urban land planning, all above factors are playing important roles on affecting the layout of electric vehicle. These factors are classified and illustrated as shown in figure 3.
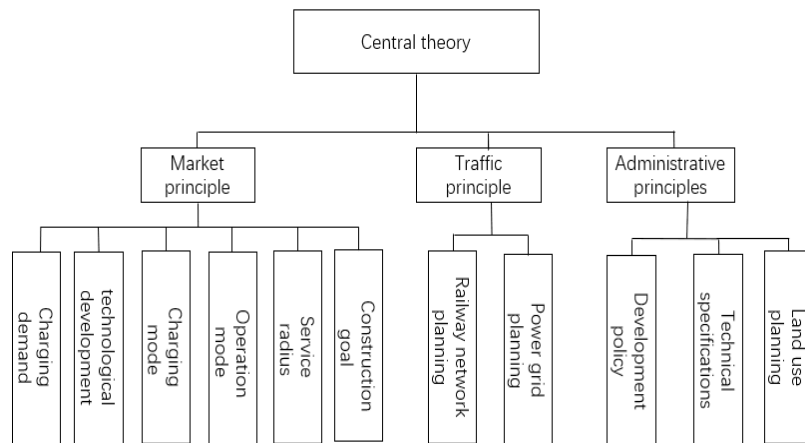
Figure 3 principle of site selection for electric vehicle charging station

2.5 Overall Development of Electric Vehicles

In 2010, there are 61 registered electric cars in South Korea, 1308 in 2014, 2917 in 2015. According to the data from the Ministry of Land, this figure should be 5099 in 2016, Pulse reported that the nationwide registered electric vehicles were over 10 thousand in the end of 2016, and 2017 would exceed 20,0000. Thus the corresponding growth tendency is drawn like figure 4 below.
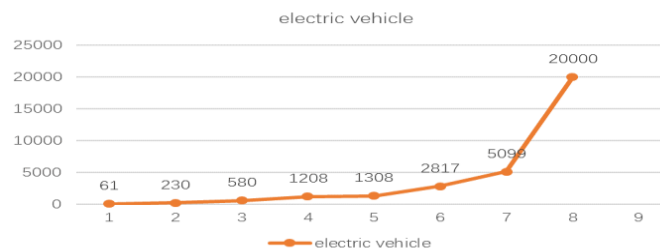

Figure 4 line map of the development trend of Korean electric vehicles

The result shows the predicted value of Korean car ownership for the next ten years.，The formula is as follows:

$$Y = \sum d \frac{(Q1+Q2)}{2} * (1+K) \tag{9}$$

Q :The volume of electric vehicles representing the current year； K ：growth rate； d ：Historical growth； Y ：The volume of electric cars in Korea.

In the formula (9), the growth rate of K is 368%, so the number of electric cars in the future Korea is predicted, such as table 2.

Table 2 forecast change value of Korean electric vehicle Suppose that 20 million of the South

Year	2010	2015	2020	2025	2030	2035	2045	2050
electric vehicle	61	2917	30000	109140	1203800	13302000	14433200	18563000

Supose that 20 million of South Korea's car ownership is converted to electric carsand calculation formula for the quantity of the electric vehicle ：

$$M = \frac{t*q}{2a} + Eqw \tag{10}$$

Formula(10)， E Current Korean car ownership， q Proportionality coefficient，Draw a change map of the related fold line like figure 5 below:
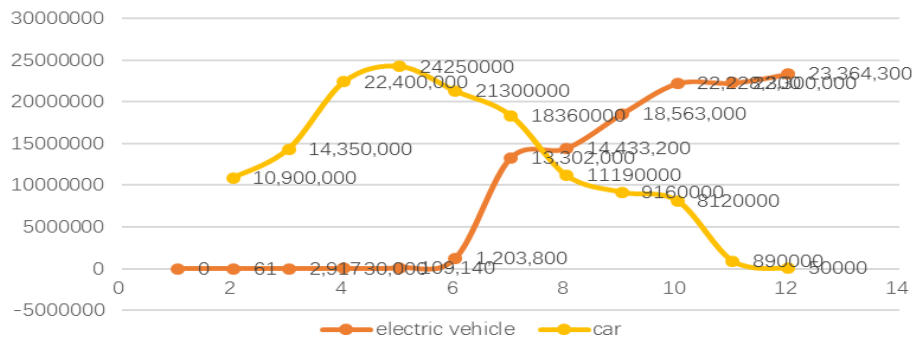
Figure 5 change diagram of the folded line of automobile and electric vehicle

when M is 2000000，Calculated q's Value

when $q = 3$ The country has 10% electric cars，and in 2024, the country had 10% electric cars.

when $q = 7$ country has 30% electric cars，and in 2027, the country had 30% electric cars.

when $q = 15$ country has 50% electric cars，and in 2035, the country had 30% electric cars.

when $q = 38$ country has 100% electric cars，and in 2058, the country had 30% electric cars.

Among them, the proportion of electric vehicles in the Korean automobile market, the support of the Korean government and the improvement rate of the national quality are all the factors that affect the growth plan.

Acknowledgments

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