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Summary Sheet

Analysis to the Construction of Charging Station Network

With the development of the electric vehicle industry, it's crucial to carry on the studies concerning the final network of charging stations. In this paper, we provide a detailed analysis to the current situation and propose the final network of charging stations and the timeline of the migration process through the establishment of four models.

We develop the Location and Distribution Model (DL Model) to solve the network. The LD model is divided into the following two sub models. First, the Forecast Model for the intra-city charging station simulates and predicts the demand of destination charging by using the Cubie method and Compound method. Second, the Building model for the inter-city charging station applies the gravity spatial interaction model to predict the number of supercharging. The result shows that the optimal number of destination charging stations is estimated to be 30080 while the supercharging stations is 7165. Besides, based on GDP and the population difference, the model addresses the charging distribution in the rural, suburban and urban.

We build a Coordination Game problem to discuss the policies between the charging infrastructure providers and the consumers. We infer that the government play a significant role in the migration, and the construction should start from the urban first.

Moreover, according to the Bass model and the new product diffusion theory, we build the Electric Vehicle Ownership Proportion Model (the EVOP model) to predict the annual market share of electric vehicles ownership. When the model is applied to South Korea, we proved that it takes about 30 years for the electric vehicle to occupy the half of the market share.
For a country with complex difference regionally, we carry out the EVOP model via the ant colony algorithm, then a developing plan can also be proposed.

Furthermore, we take the technical services changing into consideration by modify the parameters of the EVOP model. Together with the sensitivity analysis, we simulate the evolution in China and the model keep its high effectiveness. In other word, our models have high stability, high error-tolerant rate and extensive applicability.

Keywords: Multi objective Programming Approach ; Bass model ; Space gravitational model ; Charging station

Analysis to the Construction of Charging Station Network

Contents

1 Restatement of the Problem

1.1 Background and Motivation

Electric vehicle, a representative of an economically and environmentally responsible new energy vehicle, has been regarded as the main direction of the development of automobile industry in the 21st century. A growing number of countries value it and in recent years, some global vehicle manufacturing and consuming country, including the United States, are attempting to realize a complete switch to all-electric via an allround support in technology, policy and economy. Some countries are preparing to put the brakes on gasoline and diesel cars in the coming years [1]. However, it not a simple transition within the limitations of contemporary technology, the construction of infrastructure and consumptive habits. With the development of the electric vehicle industry, it's crucial to carry on the studies concerning the final network of charging stations and the supporting infrastructure system. Some countries as well as the electric vehicle manufacturers like Tesla pay close attention to this construction. According to the research from the University of Michigan, there are more than 16,000 public charging points in the United States, reaching 10% of the quantity of the existing gas stations [2].

It will inevitably encounter the following problems during the transition: First, we need to determine the charging station construction and address the early siting, location, optimal number, and distribution of charging stations based on regional difference. Second, the timetable for advancing the construction of charging stations should be proposed to achieve a perfect transition from traditional cars to electric vehicles. In this paper, we will try to tackle these two problems.

1.2 Literature review

Since the outbreak of the oil crisis in the 1970s, developing electric vehicle industry has gradually become a national energy strategy for many countries. The charging station is a fundamental supporting infrastructure to provide energy supplies to electric vehicles and has drawn extensive studies from scholars in various countries.

When it comes to the location of the charging stations, the researchers conducted different studies from macro and micro perspectives. In the macro aspects, Hatton (2009) [3] established a comprehensive network of charging infrastructures attaches great important to the popularity of electric vehicles. He proposed the construction conditions. Xu Wenchao (2011)[4] developed actor analysis to forecast the demand of charging stations. Morrow (2008)[5] evaluated and compared the construction costs of charging facilities in three different regions.

Microcosmically, ReVelle (2005)[6] summarized some classical models and extended the model by the use of an extension parameters learning. F.Glover (1986)[7] solved the model with tabu algorithm. Zhang Guoliang (2011)[8] applied the multi-objective approach to explore the location of electric vehicle charging stations intra-city and inter-city.

Focusing on the progress and the timeline of the charging network architecture, Shepherd (2012)[9] designed a dynamic model to simulate electric vehicle demand in the next 40 years in the United Kingdom. Some scholars suggested using game theory to discuss the impact from government, enterprises and consumers on this construction [10].

1.3 The Task at Hand

In order to solve those problems, we will proceed as follow:

- Construct a mathematical model to simulate and predict the number and distribution of electric vehicle charging stations when the all-electric have realized in the US. Comparing them with Tesla's network now to determine whether the its development trend is potential.

- Propose the pattern of the network and the timeline of this evolution with the consideration of the regional differences.

- Take the technological changes into consideration, then discuss the influence of those factors on the model.

- On the basis of the model, give some suggestions about the electric vehicle charging construction to the countries to help them start or ameliorate their all-electric migration.

2 Model Assumptions and Notations

2.1 Assumptions and Justifications

To simplify the problem and draw some reasonable conclusions from our model, we make the following basic assumptions, each of which is properly justified:

- According to the problems, only the personal passenger vehicles will be considered in our models. This assumption make sense since the individual consumer will become the main consumers of the electric vehicles.

- It is assumed that there are only two types of charging stations in the market in the coming future, destination charging and supercharging under Tesla standard. The assumption is based on the current development trend of electric vehicle industry in the US.

- All charging stations only provide charging service. The battery-swap service can be neglected.

- The service time of the charging stations is fixed. Namely, we assume the power provided by a charging station per day is a constant.

- We consider the number of the visitors who travel between two cities are directly proportional to the population of the city, in inverse proportion to the distances between the cities.

- The electric vehicle can be regards as a new product for the markets as it's a new potential industry in the world.

2.2 Notations

Here we listed all the variables and constants used in this paper in Table 1. Some of them will be defined in the following sections.

Table 1

Symbol	Description
$X / kV * A$	power factor
M	model correction coefficient(from 0 to 1)
Q	region automobiles
S / km	electric single charge average mileage
$P / power$	consumption per kilometer
T / h	the average time of charging
N	the average number of charging
L / km	the average daily mileage of electric vehicles
y	synthetic factors in principal component regression
b_0、b_1	fit parameters based on the Exponential method
C	All O-D set pairs in the network
c	The path between O-D set pairs

S	Set of all candidate points
s	Candidate point
L	Set of all charging stations' combination
I	the average time of charging
f_t	The transit demand on the line t
m	The number of the charging stations to be built
y_m	If the charge service can be provided by y_m, the value is 1, otherwise the value is 0.
a_{ls}	If the charging station s is in the charging station combination l, the value is 1, otherwise the value is 0.
b_{tl}	If the charge station combination l can serve the requirements on the path T, the value is 1, or the value is 0.
v_l	If all the charging stations in the charging station combination l are open, the value is 1 or 0.
$F(t+1)$	the ratio of the number of new consumers to the number of potential consumers in t+1 years
$F(t)$	the proportion of potential customers
K	the number of electric vehicle buyers in t years
Num	the current automobile market volume
Z	the maximum market potential
p	the external influence variable
q	the internal influence variable

3 Location and Distribution Model for Charging Stations

In this section, we propose the mathematical method to forecast the demand of electric vehicle charging station in city. Using the data of the quantity of electric vehicles and the gasoline and diesel car ownership, we can predict the distribution of charging station based on multi-objective programming and the Gravity Spatial Interaction model. Furthermore, we simulate the optimal distribution between urban, suburban, and rural areas according to GDP and the population difference.

3.1 The Design of the Model

In order to demonstrate our Location and Distribution Model (LD Model) clearly, we divide it into the following three sub models.

- Building forecast model for the charging station in the city: This model simulate and predict the demand of destination charging，and determine the optimal quantity of them.

- Building forecast model for the charging station between the city: In this model, we simulate the ideal number and the distribution of the supercharging between the city.

- Distribution planning of the charging station model based on GDP and the population: Based on GDP and the population difference, the model addresses the charging distribution in the rural, suburban and urban.

3.2 Sub models

3. 2. 1 Forecast Model for the Intra-city Charging Station

A single charge of destination charging lasts longer and the main location of it is usually at the places where restaurants, shopping malls, hotels, resorts, etc , are located. So we distinguish these locations from the roadways and define that most of them belong to the city's scope.

We build the model of city charging station through the above rules. It also needs to firstly consider Tesla as the representative of the current status of the US electric car industry and the current personal passenger vehicles. So that, we can determine the influence factors of destination charging stations' number. In order to get the reasonable size, we use charging needs to establish the mathematics Model relationship.

3.2.1.1 Description of the model

Because the car remaining in the U.S., level of economic development and the income of residents are closely related, we also get the statistics numbers in previous year (like the regional PEV per 1000 people and vehicle per people 1000 and the growth of GDP per capital in the United States)(source: US Department of energy) transform for multiple linear regression forecast. Finally, according to this relationship, we can build the following forecast model for the demand of the charging station in the city:

$$X = M * Q * S * P / T * N / 1000$$

$$N = L / S$$

$$q_0 = b_0 * e^{b_1 * y}$$

$$q_1 = b_0 + b_1 * t + b_2 * t^2 + b_3 * t^3$$

Considering that some family may fill their car at home, not all electric vehicles are charged at the charging station. So the model correction coefficient M is required, with a value of 0~1. At the same time, the average mileage of different types of electric vehicles in different cities is quite different. The power performance of different types of electric vehicles is also very different. The power consumption per kilometer also has a great difference. In addition, with the technological innovation, the performance of the power battery will be continuously improved, the single charging driving mileage and charging time will change. The charging demand of the charging station will continue to develop and change with the development of the city economy and the renewal of science and technology. [4].

3.2.1.2 Model solution

First of all, we need to do the data fitting and prediction of the various regions of the Q, with the introduction of a mathematical model . Secondly, by comparing each model and analyzing the fitting method, we find out the following two more reasonable fitting method: cubie model & compound methods.

compound methods——we pretend that private car ownership is Q, and the year is K. So we
get this equation:

$T = K - 2006$ (2006 is where our data starting)

$$q = b_0 \cdot b_1^y$$

Than we use software--SPSS to fit the data of the GDP and car ownership. While, the result is that: $R^2 = 0.953$

The analysis shows that the model fit well with the actual data in the early stage, but the gap is bigger in the later stage. This obviously has a great influence on the later prediction. Therefore, the model needs to be corrected.
We get rid of the ‘include constant equation’ in the SPSS and make b1 to be 1. Than b_2 comes to a separate estimate.

Now $R^2 = 0.987$

And fitting it again

Now $$R^2 = 0.996$$

Finally, we take it into the original formula to calculate the estimated number of electric cars in the cities in the states of the United States.

The Q value is calculated by vehicle per 1000 people. With it, we can achieve the X through the equation: $$X = M * Q * S * P / T * N / 1000$$

Taking the states of the United States as a settlement and taking the cities of the States as units, the destination charging distributed in the US is saved in a number way, and the X with q_1 will be fitted twice to reduce the errors.

At the last, the curve of the two fitting models can be obtained

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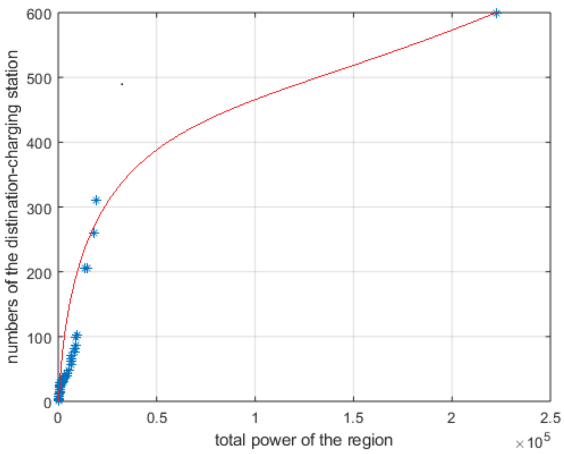

Figure 1: Relationship between regional power and charging station

Then it is brought in one by one in the curve model, and finally the data is achieved. Because of the great amount of the data, the sum is only displayed only in the unit of state.

Table 2: Amounts of the destination charging stations by state

State	Amounts	State	Amounts	State	Amounts
Alaska	461	Kansas	512	Georgia	588
Rhode Island	442	Maine	482	Virginia	735
Delaware	579	New Hampshire	689	Maryland	525
Hawaii	412	Iowa	473	Connecticut	647

District of Columbia	1402	Alabama	539	Ohio	567
Nebraska	494	Tennessee	453	Illinois	632
Kentucky	615	Indiana	509	Arizona	697
Vermont	525	Wyoming	698	Michigan	446
North Dakota	660	New Mexico	540	Pennsylvania	599
Oklahoma	279	Missouri	546	Colorado	662
Mississippi	398	Utah	474	New Jersey	523
South Carolina	475	North Carolina	491	Massachusetts	703
South Dakota	497	Minnesota	650	Oregon	664
Idaho	327	Wisconsin	537	Florida	526
Arkansas	1235	Montana	476	New York	636
Louisiana	601	Nevada	493	Texas	696
West Virginia	405	Washington	826	California	1039

The number of destination charging stations in the United States is estimated to be 30080.

3. 2. 2 **Building Model for the Inter-city Charging Station** [8]

For electric vehicle charging stations, the service objects include not only the needs generated by the destination or the origin, but also the crossing demand flow on the daily fixed routes. The main purpose of the Tesla supercharging is to provide charging support for long distance driving, which only takes a few dozens of minutes to fully charge. For the electric vehicle users in the city between the long distance driving situation, what they really need is to charge in the route , so we will use multi objective planning and Spatial Gravity Model to study the inter city electric vehicle charging station location problem. For electric vehicles, the condition of running mileage under the full electricity in the battery is still limited. To complete the long-distance running, you need to charge the vehicle when it needs charging. The driving mileage is a very important factor, which is deeply related to the number of charging stations and charging station construction in a position, to meet the needs of network for vehicle.

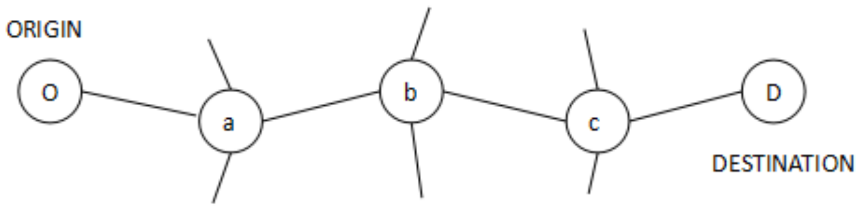

Figure 2: network

Here is a given network G (V, A), where V represents a collection of all nodes in the network while A represents a network. As shown above, it is assumed that the point a, b, and c are in the same route O-D in the network, then Logic of Vehicle Range can be expressed as follows:

(a) if the vehicle can travel from a node to the B node, it means that the residual quantity of the vehicle is bound to be greater than the distance from a node to the B node. If the power supply is insufficient, it must be charged at a node.

(b) if the vehicle needs to be charged in the node a, then the battery charge at a should not exceed the difference between the maximum capacitance of the vehicle battery and the remaining power of the vehicle at the node a.

(c) the remaining capacity of the vehicle at the node B is roommate, whose remaining power at the last node a is determined by the amount of power added at the node A and the amount of electricity consumed from a to B.

Through these three conditions, the decision conditions of the network G (V, A) in the model can be established.

3.2.2.1 Description of the Model

Without considering the road conditions and driving change, electric cars in a full charge of the case the vehicle mileage is certain. We constructing a multi objective programming model to explain how the construction of charging stations in the city on the road network, so that it can meet the needs of long-distance travel vehicles. The following is as follows:

$$Max \;\; Z = \sum_{t \in T} f_t y_t \tag{3.2.1}$$

$s.t.$

$$\sum_{l \in L} b_{tl} v_l \geq y_t \quad \forall c \in C \tag{3.2.2}$$

$$a_{ls}x_s \geq y_l \quad \forall l \in L; s \mid a_{ls} = 1 \qquad (3.2.3)$$

$$\sum_{s \in S} x_s = m, \qquad (3.2.4)$$

$$x_s, v_l, y_m \in \{0,1\} \ \forall s, l, m \qquad (3.2.5)$$

Among them, the objective function (3.2.1) to maximize P charging station can serve the passing demand constraint; (3.2.2) said at least one charging station can meet the requirement of Q combination charging path, the charging station combination is possible only by a charging station, may be composed of two or more service station; constraint (3.2.3) to ensure that only when the charging station charging stations in all combinations of H are open when the value is 1, or 0; constraint (3.2.4) said to the construction of P charging stations; constraint (3.2.5) defines three 0-1 decision variables.

3.2.2.2 The determination of the demand for the passing of the road

In view of the location of the charging stations between cities, the demand for the passing of the electric vehicles through the path should be obtained in advance. In reality, especially in the large traffic network of the United States, there are many paths between cities, it is difficult to get the demand on each path. In this paper, the space gravitational model is introduced to calculate the traffic demand between network nodes.

The idea of gravity spatial interaction model is that the volume of traffic between cities is directly proportional to the number of two cities' people, and is inversely proportional to the distance between the two places. For a given network model in G (V, A), V is the set of all nodes on the network, A is the set of all edges of the network, K is the set of all candidate points in the network (K,V), assume that the user has determined the shortest path between O at D, and the shortest as the path route, according to the space gravity model, the route Q (q,Q) on the demand for traffic crossing:

$$ft = Bw_i^{\beta} w_j^{\beta} / r_{ij}^{b}$$

While in this equation, f_t represents the transit demand on the line t, and line T represents the route between the city i and the city $j, w_i, w_j (i, j \in S)$) represents the number of users of electric vehicles that are located in the city i and the city j, the number of potential users with charging needs. r_j^i means the shortest distance between the city i and j. B, b, β is calculated according to the previous data through the regression model. b represents the extent of the influence of space distance on gravity.

β indicates the relationship between the number of electric vehicle users and the number of charging demand. β indicates the proportional constant of the model in a specific network.

3.2.2.3 Model solution

In order to simplify the algorithm, we have obtained three coefficients in the above model, based on the previous study of the gravitational model of the metropolitan area

$$L = e^{5.282};\quad \beta = 0.837;\quad b = 0.778.$$ [11]

In combination with the data obtained before, because of the large amount of urban data, this article has been integrated into the state.

Table 3: Amounts of the supercharging stations by state

State	Amounts	State	Amounts	State	Amounts
Alaska	82	Kansas	87	Georgia	149
Rhode Island	75	Maine	79	Virginia	184
Delaware	123	New Hampshire	125	Maryland	148
Hawaii	65	Iowa	86	Connecticut	179
District of Columbia	322	Alabama	121	Ohio	140
Nebraska	93	Tennessee	130	Illinois	160
Kentucky	117	Indiana	144	Arizona	197
Vermont	91	Wyoming	226	Michigan	114
North Dakota	151	New Mexico	152	Pennsylvania	150
Oklahoma	19	Missouri	139	Colorado	170
Mississippi	55	Utah	123	New Jersey	139
South Carolina	77	North Carolina	127	Massachusetts	183
South Dakota	94	Minnesota	180	Oregon	171
Idaho	34	Wisconsin	151	Florida	127
Arkansas	294	Montana	159	New York	212
Louisiana	101	Nevada	127	Texas	181

West Virginia	57	Washington	205	California	350

The number of supercharging stations in the United States is estimated to be 7165.

3.2.3 Charging Station Distribution Model Based on GDP

To figure out how should the charging destinations to be distributed in the US, we must know the differences between rural and suburban and urban. Depending on the areas that are being described, each one of these three words can explain the surrounding area and the amount of people in any given area.
In the United States, urban areas are defined by a population of more than 1,000 people per block of area. Rural areas are the least populated areas. Suburban areas have a larger population than rural areas; however, urban areas have a larger population than both.
Obviously, it is also very important to consider about the GDP of every single places. But, as we see in the above, the population is the most important parameter we should consider about.

So, we use the model we made in the above, and divide every places of U.S. into three parts. Last but not least, we match it with the numbers of stations. Finally, we can get the relationship of them.

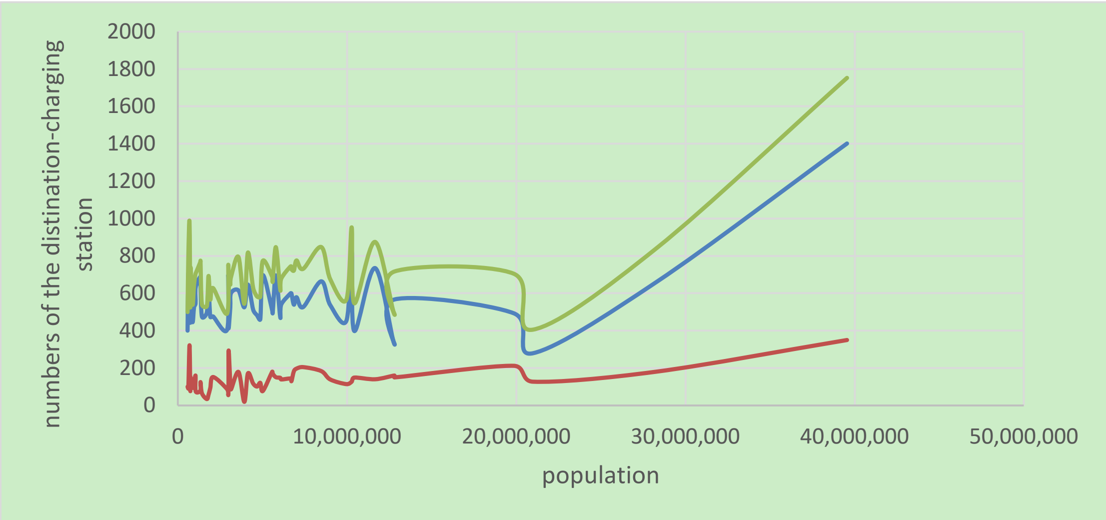

Figure 3: The relationship between population and charging station

The red line represents the supercharging stations' numbers with the population and the blue ones represents the destination charging. Of course, the green one means the relationship between the total charging stations and the population.

After that, we use Rural and Suburban and Urban data to make quantitative analysis and linear programming to predict and compare the demand. Finally, we get roughly the following data of the US.

Table 4: Result

	Rural areas	Suburban areas	Urban areas
destination charging	5264	9447	15186
supercharging	1632	1850	2492
summation	6896	11297	17678

4 The Electric Vehicle Ownership Proportion Model

In this section, the game theory is applied to address and optimize the sequence of building the charging stations. Meanwhile, we modify the BASS model to simulate the evolution of the all-electric migration. With these two conclusions, we illustrate the model with an example.

4.1 The Influencing Factors of the EVOP Model

Before the prior to the popularity of the electric vehicle, due to the high input costs, the lack of policy supporting and the obstacle of building charging service, some existing charging stations are used inefficiently, some of which even lie idle. At the meantime, the worry about the battery life and the infrastructure system hinder the progress of reforms. As a result, there is a charging difficulty paralleling the charging station idle problem. Consumers are not satisfied with the convenience of the electric vehicle, while the electric vehicle manufacturers abandon the construction because of the high investment and low repayment. If we can't break the vicious circle, the operation of charging infrastructure will be unsustainable.

To further explore the relationship in the markets, we introduce the game theory as follow:

Let the charging infrastructure providers' policy set as {supply, don't supply}, and the set of policy for consumers is {use, don't use}. Table 5 show the 2×2 coordination game problem [12] applied to find a better game strategy.

Table 5: coordination game problem

	Charging infrastructure providers	
Consumers	Supply , Use	Don't supply , Use
	Supply , Don't use	Don't supply , Don't use

Regardless of the intermediate state of the game, positive adjustments can be made when the governments provide policy and financial support to the charging infrastructure providers, the building of charging infrastructure networks can be proceeded continuously. Therefore, when the governments and the charging infrastructure providers successfully promote the development of charging service emerging markets through a sustained large capital investment, the game between consumers and charging infrastructure providers will gradually change from the initial state of the pure strategy Nash equilibrium {Don't supply , Don't use} to the new pure strategy Nash equilibrium {Supply , Use} through the intermediate state of {Supply , Don't use}.

At the same time, the distribution of charging stations should agree with the traffic density and the charging demand of electric vehicles. However, in the urban or rural area, the per capita income and the real purchasing power are quite lower than those in urban areas. For them, the charging facilities maintenance costs are high. According to these analysis, we suggest that South Korea should establish a number of charging stations in urban first, and they are supposed to increase the number of the charging stations and optimize their layout with the dynamic change of the electric vehicle ownership.

4.2 The Design of BASS model

The BASS model applies the conditional likelihood function to predict the market share movement of a new product from its introduction to market saturation. The discrete time version of the model manifests as:

$$F(t+1) = p*[1-F(t)] + q*F(t)*[1-F(t)]$$

$$S = mNumF(t)$$

where $F(t+1)$ represents the ratio of the number of new consumers to the number of potential consumers in $t+1$ years， $F(t)$ indicates the proportion of potential customers who have purchased the electric vehicle in t years. m, p, q represent the maximum market potential, the internal influence variable (innovation coefficient) and the external influence variable (imitation coefficient) respectively. S denotes the number of electric vehicle buyers in t years, while Num equals to the current automobile market volume.

When a country started to promote the installation of electric vehicle charging points, the all-electric vehicles can be considered as the process of a new product introduced to the market. Hence, we refer the new product diffusion theory to analyze it. In addition, we use BASS model to forecast its diffusion ratio. Then we can obtain the share of private electric vehicles in the automobile market. By determining the coefficients of this three variables, m, p, q 、 , we can predict the annual share of electric vehicles ownership. Besides, the number of the electric vehicle buyers in each period is equal to $F(t)$ times m .

For the value of this three variables, m, p, q , we determine m . from the market researches data.

We develop p、 q and q to distinguish consumer behavior difference. p is defined to shows the internal factors, we think this group of consumers can adapt to the new type of transport vehicles quickly, and don't attach great importance to the network of charging infrastructure. Therefore, their travel need is easy to satisfy and more likely to travel in a short distance within the electric vehicles' battery life, which means the battery life affects a small part on customers' purchase intention. The value of p is between 0.01 to 0.03. Thus, we value it as 0.015.

q is the opposite of p , This part of the consumer's buying behavior is influenced not only by other consumers, but also by the charging network. The value of p is between 0.3 and 0.7, and rarely more than 0.5. We consider the government will continue to promoting the electric vehicles, and the reference value is 0.35.

4.3 Timeline Forecast of Korea EV Overall Development Plan

In this section, we take South Korea as an example to discuss the issue of the electric vehicles market share based on the electric vehicle ownership. The model is utilized to this example with the following assumptions:

- The electric vehicle is a new product preparing to be introduced in South Korea.
- The number of charging points set in the market will not cause any adverse effect on the electric vehicle ownership.

Eventually, this model leads to a computer simulation of the following table 6 and figure 4:

Table 6 Electric vehicle market share over time changes

Market Share (%)	Time (year)
10	7
30	18
50	33
90	135

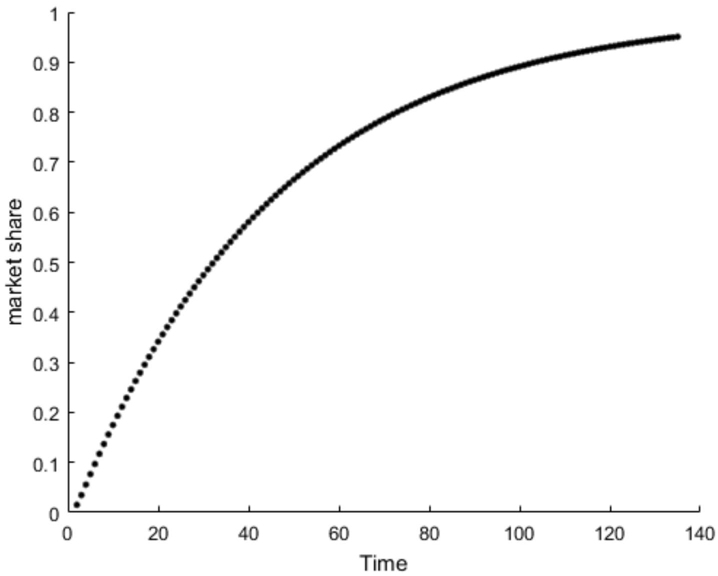

Figure 4 : Electric vehicle market share over time changes

By analyzing the above result, we can find:

In the first 30 years, the market share increase rapidly over time. According to the current private car ownership in South Korea, we can predict that the market share of electric vehicles will reach 10%, 30%, 50% and 90% in around 7 years, 18 years, 33 years and 135 years respectively. It's glad to find that after only 30 years of development, the electric vehicle can account for nearly half of the markets and gradually occupy most of the markets.

5 Improving the Model

The rapid economic development provides a huge space for the boom of private cars. The continuous growth of private cars will lead to the deviation when we use the Bass model to predict the electric vehicle ownership.

There are many factors that affect the private car ownership, such as per GDP, total retail sales of consumer goods, total investment in fixed assets in the whole society, etc. According to the World Bank's research, the private car ownership is proportional to

GDP. We can predict the relationship between GDP and private car ownership through nonlinear regression prediction method, elastic prediction method, improved elastic prediction method and quadratic curve exponential smoothing method to improve the accuracy of the Bass model.[13]

6 Model Evaluation & Sensitivity Analysis[14]

The main purpose of the section is to discuss the feasibility of the former models and evaluate the performance of the Electric Vehicle Ownership Proportion Model when meeting complex situation. Regarding to the evolving technical services, we hold the view that it will promote the thrive of the electric vehicle industry. Then we test the sensitivity of the last model in the process of electric vehicle migration in China.

6.1 Meaningful results from the model evaluation

Careful evaluation is necessary to ensure whether the models are effective. For the regions which are various in geographical location, population density, and economy in a country, we can classify the regions according to the differentiation, and use the real data of the regions into the model and solve the coefficients by the Ant Colony Algorithm to design the suitable development plan for a country.

Taking the evolving technical services into account, we use this three variables m, p, q to express the factors changing. As the growth of the car-share or ride-share services, the purchase demand of the electric vehicle will decrease. That means the value of m will go down, in other word, the electric vehicle ownership will reduce. The value of p will increase, resulting in a raise of purchase. The new technique and advanced product with artificial intelligence will attract more consumers to buy electric vehicle.

6.2 The Sensitivity of the EVOP Model

In order to test the accuracy of the model, we choose the market share changing in China as the test value. The choice make sense since China is a developing country with huge difference between urban and rural, and the electric vehicle industry is a fledgling sector starting from 2010. Using the current data, we get the conclusion that the market share will reach to 50% after 32 years. The result is in line with the national electric vehicle planning in 2040. Figure 5 show the specific data of our prediction.

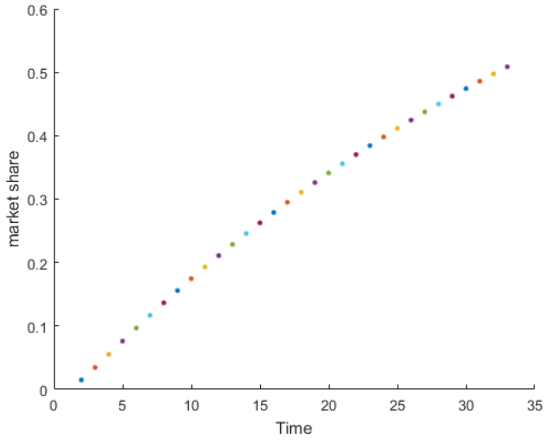

Figure 5

7 Conclusion

Through the establishment of four models, we propose the LD Model to forecast the demand of electric vehicle charging station in city. Based on the quantity of electric vehicles as well as the various types of vehicles' daily power consumption, we can predict the distribution of charging station. Taking the long time traveling demand into consideration, we develop Building forecast model for the charging station between the city

.

Furthermore, the Bass model inspired us to use the market share to manage the works. We develop a comprehensive consideration including GDP, traffic conditions, the attractiveness of electric vehicles and consumer behaviors, and set three variables to predict the annual share of electric vehicles ownership. We proved that it will take about 30 years for the electric vehicle to occupy the half market share.

After determining the number and location of the electric vehicle, we can design the suitable development plan for a country via the Ant Colony Algorithm. Then we analyze the market environment when technical services changing. Together with the sensitivity analysis, we simulate the evolution in China and the Bass model keep its high effectiveness.

7.1 Strengths and Weaknesses

7.1.1 Strengths

Our main model's strength is its enormous edibility. For instance, population, travel condition, GDP…Including all these factors into a single, robust framework, our model enables.

Our models are adaptable to different conditions.

Our models have broad application prospect.

We can modify our models conveniently.

7.1.2 Weaknesses

Modification of the model parameters requires a lot of data.

8 Handout

Dear President,

Thank you for attending this international energy summit. It's our honor to talk with you in this special way. We are glad to see the great contribution you and your nation have made for global environmental protection.

With the development of battery and charging technology, electric vehicle has been regarded as the main direction of the development of automobile industry in the 21st century. However, it not a simple transition within the limitations of contemporary technology, the construction of infrastructure and consumptive habits. To realize the prefect migration from the traditional vehicle to electric vehicle, it's crucial to carry on the studies concerning the final network of charging stations and the supporting infrastructure system.

As the premise and basis of Electric vehicle`s development, Electric Vehicle Charging Infrastructure is still in the starting and demonstration stage, from the quasi-public goods attributes of EV charging infrastructure, simply by the government or the market for investment in building companies are not feasible, Therefore, the construction of electric vehicle charging infrastructure needs the government and businesses should work together to build an electric car charging infrastructure. At the same time, the government should give full play to the function of guiding and attracting social capital to participate in the expansion of charging infrastructures. Considering the traffic density and charging needs, urban master plan and road network planning, the status of the country's power transmission and distribution network for the corresponding charging infrastructure planning and design,the government should first build a network of charging infrastructure in high-density, densely populated and easily accessible cities and high-traffic areas, promote the realization of electric vehicle charging infrastructure diversification. Gas vehicles are forbidden to be sold when the market share of electric vehicles reaches 50% (about 20-50 years), and forbidden to use when the market share of electric vehicles reaches 90% (about 30-70 years).

Thank you for taking the time to read this handout. We would appreciate it if the suggestion can inspire your planning. We are willing to see a global cooperation in this outstanding migration and an epoch-making reform will achieve in the coming future.

Together, individual can make a difference. We are on the path of the low-carbon world and sustainable development.

Team # 88894

References

[1] http://money.cnn.com/2017/09/11/news/china-gas- electric-car-ban/index.html

[2] https://baijiahao.baidu.com/s?id=1588565718904543778&wfr=spider&for=pc

[3] Hatton, C.E., Beella, S.K., Brezet, J.C., et al. Charging station for urban settings: the design of a product platform for electric vehicle infrastructure in Dutch cities. International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium, 13-16th, 2009.

[4] Xu Wenchao,Niu Tao,Yan Linli,Han,Influence Factors and Predicting Method of the Demand for Electrical Vehicle Charging Station,Jiangsu Power ***DesignInstitute***，2011，30（3）：41~43.

[5] Morrow, K, Karner, D, Francfort, J. Plug-in Hybrid Electric Vehicle Charging Infrastructure Review. Idaho Falls: Idaho National Laboratory, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. 2008.

[6] Re Velle, C S, Eiselt, H A. Location analysis: A synthesis and survey. European Journal of Operational Research. 2005, 165(1): 1~19.

[7] F. Glover. Future paths for integer programming and links to artificial intelligence. Computers & Operations Research. 1986, 13(5): 533~549.

[8] Zhang Guoliang. Study on Location Selection of Electric Vehicle Charging Station in City and City[D].Tianjin University,2012.

[9] Factors affecting future demand for electric vehicles: A model based study[J] . Simon Shepherd,Peter Bonsall,Gillian Harrison. Transport Policy . 2011

[10] Zhang Jingjing . Multiparty Analysis on Development of Electric Vehicle Charging Facilities Based on Game Theory[D].Beijing Jiaotong University,2011.

[11] Hu Dandan,Yang Chao,Yang.Research on Location Problem Based on Gravity Model[J].Highway traffic science and technology,2009,26(05):103-106.

[12] Jörg Oechssler. Decentralization and the coordination problem[J]. Journal of Economic Behavior and Organization,1997,32(1).

[13]Chen Chuyue. Charing and Swapping Demand Ananlysis and Forecast of Elctric Vehicles [D].Beijing Jiaotong University,2015.

[14]Liang Huiling,Lin Yurui. Model Analysis of Private Car Ownership in China[J].Industrial & Science Tribune;,2014,13(22):78-79.