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2018
MCM/ICM
Summary Sheet

Location Problem Model of charging stations

summary

Our research establishes three basic models to determine the number and distribution of charging stations of electric vehicles(EV). In addition, we create Multi-Stage Decision Model to propose charge station plan and growth plan timeline. At last, we construct classification system based on six indicators.

In order to locate the two types of charging stations in urban, suburban and rural areas, we establish three models:Towards destination charging station distribution in urban and suburban areas, we cluster the demand points, which is obtained by population density diagram. Towards supercharging distribution in urban and suburban areas, we build Optimization Model, whose objective is minimizing expenditure, and adopt Tabu Search Algorithm.We don't consider supercharging exists in rural areas.So, towards supercharging distribution in rural areas, charging stations are distributed on highways. We utilize Gravity Spatial Interaction Model to confirm traffic volume.

We choose South Korean to research. According to three basic models, we conclude that it could switch to all-electric vehicles in the US. The total number of charging stations in the US we predict is 0.458 million at 2075, when everyone switches to all-electric personal vehicles. And we also can obtain the ratio of charging station number in urban, suburban, rural areas in the US is 5.27: 4.36: 1. Towards a nation, the distribution of charging stations in the US is dense in east and west coast, while that of Korean is centered distributed in Soul and Busan. Towards a city, take Los Angelas as an example, destination charging largely distributes in residential areas, while supercharging is densely situated in traffic thoroughfares.

To predict growth timeline, we create the Multi-Stage Decision Model. Through calculation, we spend 5, 20, 31, 62 years to arrive at 10%, 30%, 50%, 100% electric vehicles. Then the income under the situation of building chargers first is three times than that under the situation of increasing customers first. In addition, concerning to the charging station plan, we prefer to build charging stations in cities then mix city-based and rural chargers. As for key factors related to growth plan, per capity annual income distribution is a crucial indicator, which influence occupation rate.

We build a growth mode classification system towards various countries. The criterion of classification is the trend of increasing rate, which categorize all countries into three growth mode: steady, slow-fast, fast-slow. Key factors triggering the first mode includes large plain ratio and high technology level. Key factors triggering the second mode includes sufficient oil reservation and low technology level. Key words triggering the third mode contains uneven population density,etc.

Keywords: Multi-Stage Decision Model, Tabu Search Algorithm, Clustering, Optimization model, Gravity Spatial Interaction Model

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1 Introduction

1.1 Background

With the rapid development of social economy, serious energy shortage and global environmental pollution have gradually attracted wide attention around the world. Nowadays, electric vehicles(EV) have become an emerging energy industry, which is valued by all countries and regions in the world because of its significant advantages in cleanliness and energy conservation.[1]

However, it is worth paying special attention to the fact that although electric vehicles have already shown up for a long time, the promotion of electric vehicles in the market still moves slowly. One of the most important reason is that the electric vehicles have poorer battery life and less battery capacity than traditional vehicles. And it is not easy for consumers to find convenient places to charge when they encounter the problem of lack of electricity. Only by establishing enough charging stations, the consumers will have intend to purchase and use them. So, the increasing demand of consumers will inspire producers to sell more and gradually promote the development of electric vehicles.[1]

Therefore, in order to popularize electric vehicles at this stage, in addition to continue to break technology barriers, we must reasonably construct a sufficient number of vehicle charging stations in all the right places so that people can use their vehicles for daily business and occasional long-distance trips. For this reason, the objective of our research is to establish a site selection model for vehicle charging stations to satisfy the demand of charging and apply a scientific solution for future construction.

1.2 Restatement of the problem

First of all, based on the current and growing network of Tesla charging stations in the US, decide whether the popularization of Tesla portend that a complete switch to all-electric vehicles will appear in the US. If it could be true, determine the number of charging stations needed by consumers, and the distribution in urban, suburban, and rural areas. Then, select a country from South Korea, Ireland, or Uruguay and repeat the above first step, ignoring the transition time required. And consider the influential factors on geographical layout.

Furthermore, formulate the construction process of the charging network of the chosen country from zero chargers to a full electric-vehicle system. Specifically, determine investment priority of city, rural areas or a mix of both, and of building charging stations or promoting vehicle purchases. In this process, consider the key factors on charging station plan. In addition, based on our growth plan, list the timeline of the full evolution to electric vehicles in the chosen country, which includes time duration when it reaches 10%, 30%, 50% or 100% electric vehicles. In this process, consider the significant factors on growth plan timeline.

In order to apply this plan to different areas in the world, consider what different growth approaches to select in countries with very different geographies, population density distributions, and wealth distributions. Discuss the feasibility of creating a classification system that would help a nation determine the general growth model.Finally, explore how new emerging technologies, such as car-share and ride-share services, self-driving cars, impact on the increasing use of electric vehicles.

1.3 Analysis of problems

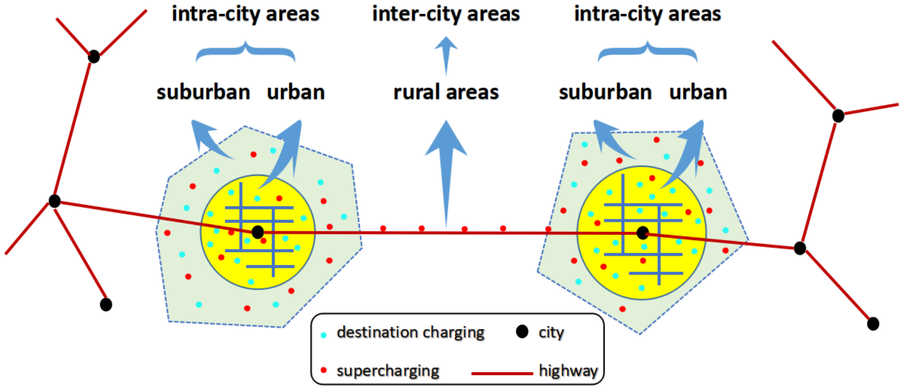

Figure 1: The concept diagram of distribution of charging stations

- Towards task1,2A

  Without transition time, we assume all citizens who have personal vehicles migrate to use electric vehicles. There are two types of charging ways:One is destination charging, which is generally located in residential areas and suitable for Tesla owners who have a personal garage or a driveway with power. The other is supercharging station, which is always distributed in highways and densely populated areas like shopping center, business zone, etc. So, we consider destination charging stations is located in intra-city areas while supercharging stations is situated in intra-city and inter-city areas, as shown in Figure 1.

  – Towards destination charging station distribution in intra-city areas, we intend to obtain the personal vehicles density distribution in a city through clustering and allocate the number of charging stations and its placement according to proportion.

  – Towards supercharging distribution in intra-city areas, we build the optimization model to achieve the goal of minimizing the expenditure.

  – Towards supercharging distribution in inter-city areas, we establish the Gravity Spatial Interaction Model based on Graph Theory. Thus, we can compute the relation intensity between two cities and determine the number of charging stations and its placement.

- Towards task 2B,2C

  When investing the development of electric vehicles, we estimate the priority of rural areas and city-based areas based on historical experience of other countries. In order to estimate the priority of building charging stations or inspiring purchases, we construct the function of income and cost, and make the decision according to profit of two options. Utilizing the diagram of per capity annual income probability distribution, we establish the Multi-stage Decision Model to make the growth timeline and judge whether it arrive at 100%-electricity.

- Towards task 3

  Towards various counties in the world, we define six influential factors. And regulate the classification criterion of a nations is the factor which the development situation of the nation is strongly related to. In order to determine the category a nation belongs to, we clustering the data of six indicators and obtain the factors a nation is associated with.

- Towards task 4

  According to the influence of new technologies on electric vehicles, we acknowledge their characteristics and current development situation related to the development of electric vehicles, also considering the price and mature degree of new technology, predict the impact on EV.

1.4 Our Works

Our aim is to establish a model to describe reasonable and economical geographical layout of two types of charging stations. And put forward the charging station construction proposal and electric vehicles growth timeline. Furthermore, design different schemes towards other nations and explore the impact from the development of new technologies. Following is our dilemma and the solving approaches:

2 Assumptions and Justifications

- We focus only on personal passenger vehicles, including cars, vans, and light trucks used for passengers. It is convenient for us to determine the scope of our problem. At the end of our paper, we will make brief comments on the relevance of the results and conclusions on commercial vehicles.
- We classify the layout of charging stations into two areas: intra-city areas and intercity areas, which is convenient for us to divide the layout problem into two situations. And we define intra-city area includes urban and suburban area, and intercity area includes rural area.
- Same charging stations have the same service radius. And we define a demand point to represent the demand of charging in the region.
- We obtain all candidate points of charging stations through considering the distribution of demand points, environment condition and safety condition.
- Battery is fully charged when customers go to charging station every time.
- Customer know all the situation of charging stations, and they can automatically choose the shortest station.
- The velocity of electric vehicles are the same, and we donâĂŹt take traffic jam into consideration. So, the cost of charging of customers depends linearly on the distance.
- Remaining capacity of battery enable electric vehicles to drive to charging stations.That is to say, there is no emergency of leaving electric vehicles in the street.

- There are enough number of charging outlets in every charging station, namely, people should not wait in line.

3 Notation

4 Determine the location distribution

4.1 Distribution Model for destination charging in intra-city areas(DM)

We believe that the demand for fast charge and slow charge are different. Due to the extremely long time of normal charge, normal charge preferentially focuses on the area where people live. The supercharge time is short, which can save a lot of charging time. Therefore, the supercharge station is usually located on road side. Through the population thermodynamic picture, we can know the distribution of population density. We use Monte Carlo simulation to randomly allocate population distribution maps. The higher the population density, the more intensive the investment point is. We think all the points we cast can be regarded as demand points, and the coordinates of these points are clustered by means of k-means clustering, and the center of each cluster is calculated as the position of our charging station. As for fast charge, we extracted the traffic network information in Google Map through threshold. Similarly, we use Monte Carlo simulation method to get sufficient candidate points distributed on both sides of the road, Between the distance of the judge, the candidate points for screening, so that we get evenly distributed, large enough intervals of the distribution of booster stations.

4.2 Optimization Model for supercharging in intra-city areas(OM)

In order to popularize electric vehicle, there are many factors to shape the number and distribution of charging stations. Towards Tesla, it should consider whether the number

symbol	description
I	the set of demand points, i in I represents a demand point
J	the set of candidate points of constructing charging stations, jâĹĹJ represents a candidate poi
D_i	the number of electric vehicles which have need of charging at i
F	the initial construction expenditure of a supercharging station
λ	the cost of driving on the road per unit distance for customers
C	the number of electric vehicles the supercharging station can serve everyday
p_i	the amount of population in the region which point i represents
k_i	the average duration time between two charging times at the demand point i
n_i	the number of vehicle ownership in the region the demand point i represents
d_{ij}	the distance of demand point i to candidate point j
P	the number of supercharging station remained to be constructed in intra-city areas
V	the long-run equilibrium level of vehicle /population ratio
X_j	when it constructs supercharging station at j,$X_j = 1$; otherwise, $X_j = 0$
Z_{ij}	when there is a customer at demand point i going to candidate point j, $Z_{ij} = 1$; otherwise,Z_{ij} =

Table 1: symbol description

of charging stations is sufficient, whether the service capacity can satisfy all customers, whether the income of selling electric vehicles can cover the cost of building charging stations. Towards customers, they should consider whether it is convenient to arrive at the charging station, the time and cost they spent.Towards the government, they care about whether the location of the charging station probably cause traffic jam, security risks and environment disruption. We dispel worries from government through artificially selecting candidate location of stations.[2]

From the above analysis, the location of a charging station should not only meet the demand of users as much as possible within service capability, also control total cost: initial construction cost of a station and charging cost of users. Therefore, aiming at minimizing total cost, setting the condition that electricity supply capacity is greater than charging demand as one of the constraints, we establish optimization model to determine the number and placement of charging stations.

4.2.1 Determination of demand points and candidate points

Towards the distribution of charging demand in intra-city areas, we believe the larger population density a region has, the higher demand it will have, like shopping mall and business zones, where electric vehicle owners frequently go. Therefore, through image clustering we utilize population thermodynamic diagram to obtain the set of demand points I. In addition, in order to confirm candidate points, we randomly and evenly select the enough points on the map and artificially exclude the inappropriate points. Our final goal is to filtrate the points of charging stations we plan to construct, and obtain the distribution and quantity of supercharging stations in intra-city areas.

4.2.2 Establishment of Optimization Model

Before listing the objective and constraints of our function, we denote some variables we used in the function:

$$D_i = n_i \frac{1}{k_i} \tag{1}$$

Equation (1) means that the number of electric vehicles which have need of charging at i (D_i)can be represented in the product of the number of vehicle ownership at i (n_i)and the average probability of charging times everyday, which is the reciprocal of the average time duration between two charging times at $i(k_i)$.

$$n_i = p_i V(GDP) \tag{2}$$

Equation (2) means the number of vehicle ownership at i (n_i)is the product of population at $i(p_i)$and coefficient V. $V(GDP)$ is the long-run equilibrium level of vehicle /population ratio and related to per-capita GDP. From reference[3], we determine the equation of $V(GDP)$:

$$V(GDP) = \gamma e^(\alpha e^(\beta GDP)) \tag{3}$$

Objective Minimize

$$C = \sum_i F_{x_j} + \lambda \sum_i \sum_j D_i Z_{ij} dij \tag{4}$$

Equation (4) represents total cost is minimum.$\sum_j^{F_{x_j}}$ is initial construction cost of the stations we planed to construct.$\lambda \sum_i \sum_j D_i Z_{ij} d_{ij}$ d_{ij} means consumers' cost on charging, which is directly proportional to the distance between demand point i to candidate point j.λ is the cost of driving on the road per unit distance.

Constrains

$$\sum_j Z_{ij} = 1, \forall i \in I \tag{5}$$

$$Z_{ij} <= x_j, \forall i \in I, j \in J \tag{6}$$

$$\sum_{D_i}^{Z_{ij}} <= \sum_j C x_j \tag{7}$$

$$\sum_j x_j \tag{8}$$

$$x_j \in 0, 1, \forall j \in J \tag{9}$$

$$Z_{ij} \in 0, 1, \forall i \in I, j \in J \tag{10}$$

Equation (5) means demand point i will select a candidate point j to charge. Equation(6) means if there is a consumer choose j to charge, thus we will construct a station at candidate point j. Equation (7) represents the electricity supplied by all candidate points covers the demand from all point i. C is the number of electric vehicles station can serve everyday. D_i is the number of electric vehicles which have demand of charging at i. Equation (9) and (10) limit the decision variables X_j and Z_{ij} in $0, 1$. [4]

4.2.3 Tabu Search Algorithm

Determining the location of charging stations belongs to NP-Hard Problem, which has lots of variables and complex constraints. So exact algorithms is not suitable to solve NP-hard problems. Tabu search algorithm can stimulate the short-term memory of brain and find global optimal solution step by step. In order to avoid invalid cycle count, it use tabu criterion to realize. At the same time, it use aspiration criterion to accept bad solution and ensure the exploration of valid routes in different scope. Because TS algorithm has an advantage in local search, we adopt this method to solve Optimization model.[5]

1. Construct initial solution

   The solution we need is X_j and Z_{ij}. First, traverse i, compute the distance between all demand points i and candidate points j. Secondly, select the smallest distance

d_{ij*} and corresponding $j*$, allocate the demand point i to $j*$, thus we obtain $Z_{ij*} = 1$ and D_i^{j*} have been a part of demand of $j*$. Let $i = i + 1$ and repeat the above process until all demand points have been allocated to a candidate point. Thus, the demand allocated to j is $S_j = \sum_{ij} D_i^j$. So the number of charging stations we should build is $P = \frac{S_j}{M}$, where M represents the electricity every charging station can supply.

2. Utilize modified 2-opt construct neighborhood structure

   Utilize 2-opt[6] build neighborhood solution. There are C_j^2 neighborhood solutions of an initial solution, where j is the number of candidate points. Then we divide all candidate points into two groups: To Be Built set and other candidate set. Through every 2-opt, we respectively select a point in two groups and exchange them

3. Termination criterion

   Our algorithm has two termination criterion: one is reaching up to maximum iterations, the other is regulating a number of iteration times N_s. If optimal solution is invariable after N_s iterations, we terminate the search.[4]

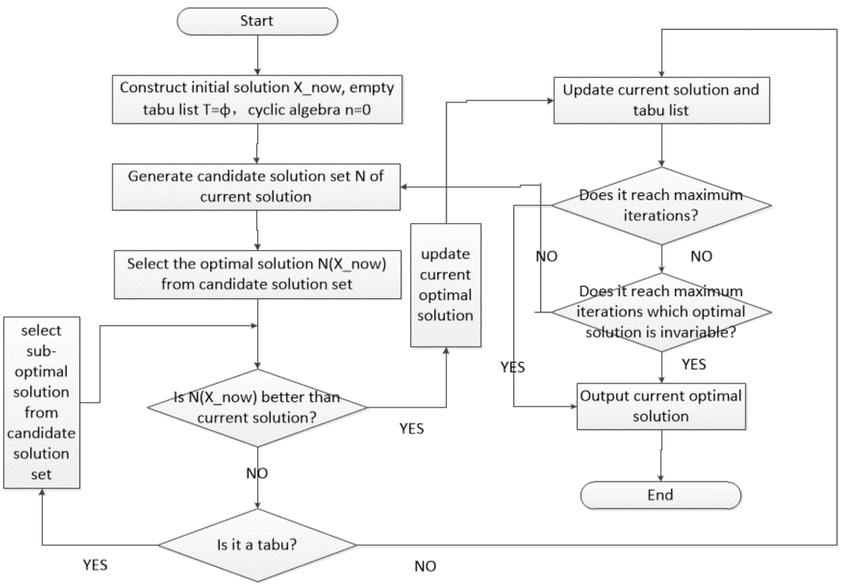

Figure 2: Solving procedures of Tabu Search Algorithm

4.3 Gravity Spatial Interaction Model for supercharging in inter-city areas

In inter-city areas, supercharging stations is located on the highways among cities. The number of charging stations is closely related to the traffic volume, distance between two cities, battery endurance ability of electric vehicles. And if we can determine the number of stations, we will allocate them evenly on the highway, which can meet the demand of customers at the most extent.

Therefore, in order to determine the traffic volume on a highway, we establish the Gravity Spatial Interaction Model(GSIM), referring to reference.[4] This model is put forward by Fotheringham[7] in 1989 and aims at determining the expression of traffic volume with some factors like population and distance. The main idea of GSIM is that the traffic volume is proportional to population in two cities, and is inversely proportional to the distance between two cities. The relation can be expressed in equation (11):

$$f_{ij} = \frac{Lw_i^{\beta} w_j^{\beta}}{r_{ij}^{b}} \tag{11}$$

where f_{ij} represents the charging demand or the traffic volume(only towards electric vehicles) on the highway between city i to city j. w_i and w_j represent the number of electric vehicle customers in i and j. r_{ij} represents the distance of two cities. L, b, β are coefficients. L means a constant of the traffic network, b is the influence degree of distance on traffic volume, and β is the relation between the number of electric vehicles users and the demand of charging. All of these parameters can be concluded through establishing regression model based on historical data.

Then we can obtain the number of stations p_{0ij} on a highway through equation (12):

$$p_{ij}k = \frac{f_{ij} r_{ij}}{L_{max}} \tag{12}$$

Where p_{ij} is the number of stations on the highway between i and j, which can be calculated by equation ([11]). k is average service times of charging stations and L_{max} is maximum drive distance after a charging, both of which can be obtained by referring to relevant reports.

4.3.1 The Analysis of task two a

Figure 21 ,is the results after clustering the demand points. Figure 22 is the distribution among urban ,suburban and rural areas. From figure 22, we can find that there is almost no normal charging stations. Normal stations densely distribute in urban and suburban areas. The number of supercharging stations is far less than that of normal stations, but it also distributes in suburban areas.

4.3.2 The Analysis of task two b

In task2, we used the same method to analyze Korea. We calculated the total number of charging stations and their distribution when all cars were converted to electric vehicles. When Korea's domestic charging station reaches 12,000, it can realize the maximum return. The distribution is as follows. It is mainly affected by GDP per capita. The distribution principle within the city is similar to that in Los Angeles. Therefore, there is no map attached.

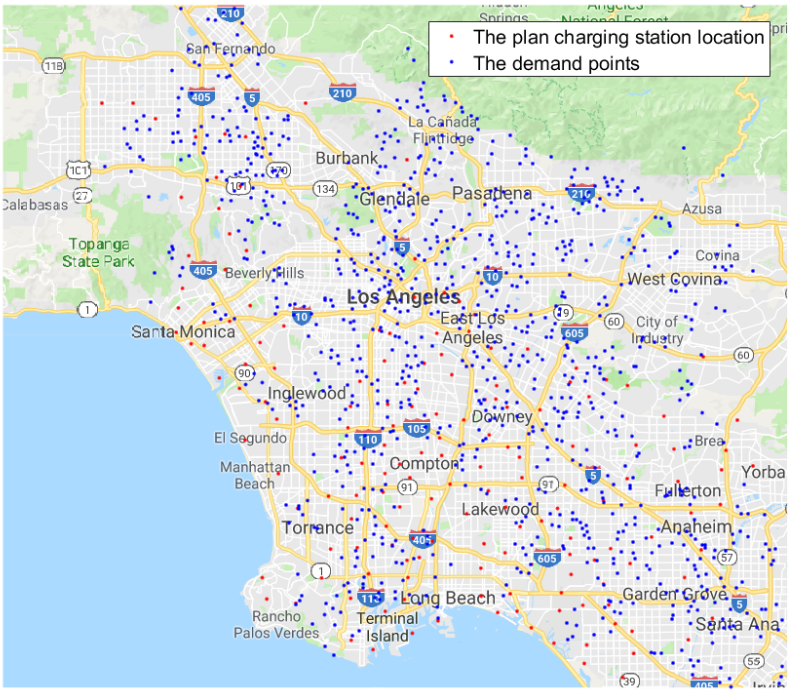

Figure 3: The plan chargin station location and the demond points

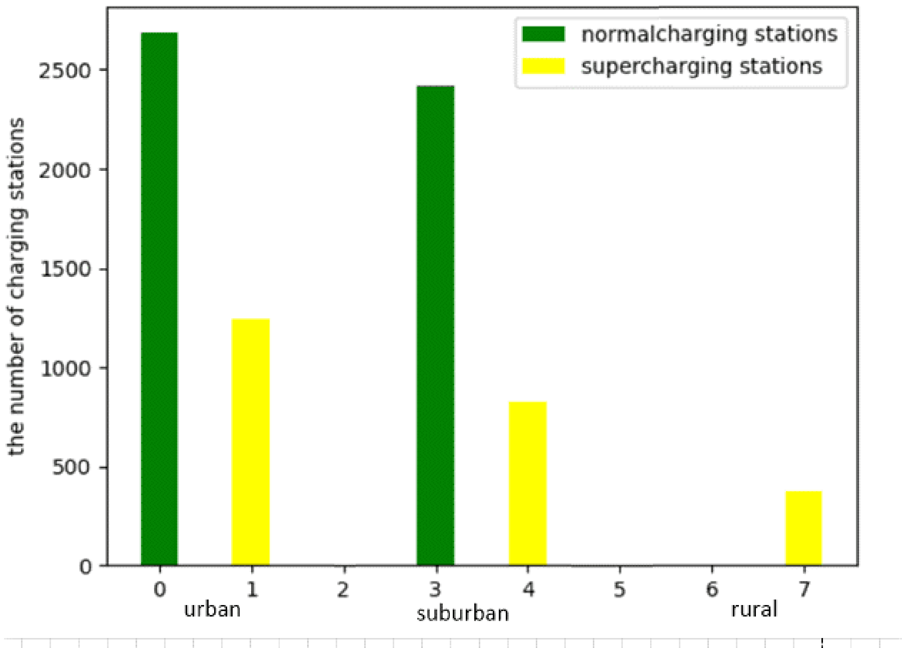

Figure 4: The distribution among urban,suburban and rural of the US

5 Proposal of the growing and evolving network of charging stations

A successful product promotion strongly relates to good sales and channel management, so it is difficult for manufacturers to balance well between them. Take popularizing the

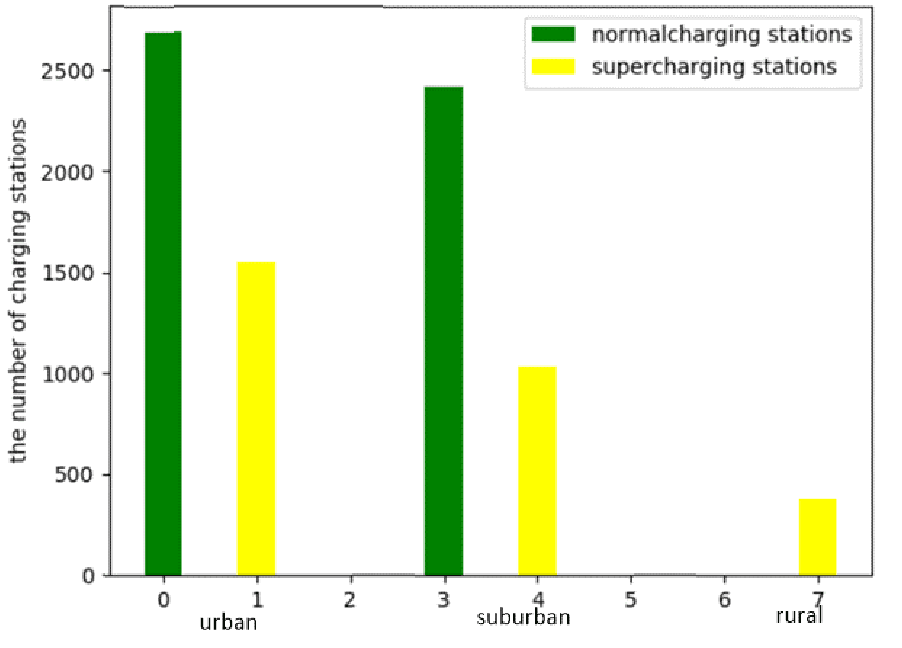

Figure 5: The distribution among urban,suburban and rural

charging stations as an example, there is also a dilemma about the promotion priority: rural or city-based, building charging stations or encouraging purchases.

5.1 Rural or City-based?

From the our observation of development situation of EV and some reference, the current market in rural areas is not good. There are three probable causes: 1) without sufficient charging stations. For the moment, the distribution density of charging stations in rural areas is less than cities.[9] [10] 2) Government subsidies in rural areas is lower than that of cities.[1] 3) Average price of electric vehicles is higher than traditional vehicles.[12] However, the EV market is still potential and optimistic.[[13]] Manufactures should still attach importance to development of EV in rural areas.

5.2 Building charging stations or Encouraging purchases?

Both increasing the number of charging stations and EV production can expedite the popularity degree of EV. When we build sufficient charging stations at first, though it costs much, it will accelerate the number of customers. Conversely, when we enhance the production and facilitate purchase, it won't cost too much but will trigger the risk of decreasing number of users, because of deficient quantity of charger. Therefore, it is not reasonable to choose to building charging stations or encourage purchases under the condition that either station number or sales is zero. So we initiate charging station number N_charge and sales volume of $EV\ N_{EVsales}$.

$$N_{charge} = N_0(\neq 0), N_{EVsales} = K_0(\neq 0) \tag{13}$$

Now that the initial values of N_charge and N_EV sales is not zero, our dilemma is transferred into the problem: Comparing the influence of increasing charging stations and enhancing sales volume on company's profit. So we describe income, cost and profit mathematically as follows:

$$Income = N_{EVsales}Price_{EV} + Prie_{ele}S_{ele} \tag{14}$$

$$Cost = N_{super(t)}Cost_{stationSuper} + N_{normal(t)}Cost_{stationNormal} + r(t)A(t)EV_{cost} \tag{15}$$

$$Profit = Income - Cost \tag{16}$$

where $N_{EVsales}$ is sales volume, $Price_{EV}$ is the selling price of a electric vehicle. $Price_{ele}$ is selling price of per unit electricity, $Supply_{ele}$ means the total quantity of manufacturer supplies. EV_{cost} is the cost of manufacturing an EV. The income for manufacturers is in relation to sales volume and electricity fee paid by consumers. The cost mainly depends on constructing two types of charging stations and producing EV.

In addition, we consider that meeting the demand of charging is the premise of two options. The constraint condition is:$PeP(\frac{CVE(t)}{CV(t)}\lambda < Npile((\frac{N_{normal(t)}}{A_{normal}+\frac{N_{super(t)}}{A_{super}}}))$

where Pe_i is average number of vehicles per person, P is total population of a nation. $\frac{CEV(t)}{CV(t)}$ is the ratio of the number of existing EV of a nation and the number of total vehicles. Lamda is a coefficient which means average charging demand of an EV. N_{pile} represents average number of chargers of a charging station. $N_{normal(t)}$ is the number of normal stations at time t. A_{normal} means the ability of supplying electricity of a normal station.

Under the condition that building charging stations first, the number of consumers attracted by charging stations at time t, defined as $p(t)$, is linear to charging stations number at time $t-1$, defined as $n(t-1)$. The coefficient and intercept is k_1 and b_1.

$$p(t) = k_1n(t-1) + b_1 \tag{17}$$

Under the condition that expediting purchases first, the number of charging stations to be constructed caused by consumers at time t, defined as $n(t)$, is linear to consumers' quantity at time $t-1$, defined as $p(t-1)$. The coefficient and intercept is k_2 and b_2.

$$n(t) = k_2p(t-1) + b_2 \tag{18}$$

Then we can calculate the profit under two selections according to equation (13) (18) and contrast them. The selection with higher profit is what we chose.

5.3 Growth Plan and whether system reaches100 %-electric point or not

In order to determine the growth approach, we denote the occupation rate of EV in the market at time t as $r(t)$ to measure the its popularity degree. There are some key factors influencing its increase, such as economical level of a nation, technology level and relevant policies like government subsidies. In our model, we mainly show the influence of economical level on growth approach.

In traditional way, we can forecast the value of $r(t)$ based on Grey Prediction Theory with the data of total vehicles sales and occupation rate $r(t)$.[14] However, the result is less than satisfactory and can not solve the problem of "which is first?". So we establish Multi-stage Decision Model to predict the development approach and growth timeline. Following is our model.

Firstly , we take one year as unit time. We initialize the first year charging station increment, this time will be based on our selection of the starting time to decide.$NA(0) = N0$

Secondly,we do a gray-scale forecast of the country's car production in each year $A_{\surd}(t)$

Thirdly,since we want to establish a model to evaluate the purchasing power of people, we define G, and in the probability density map of GDP, we integrate the number of people who want the infinite point of G to get the number of people owned by electric vehicles, f Personal GDP probability density function.

$$\sum f(x)dx = \frac{CEV}{EV} \tag{19}$$

We update the value of point G to G *, P (t) for the total population, gama is the ratio of the total number of electric vehicles to the number of stations on the charging station. F (G) is the distribution function of f (x).

$$(1 - F(G*))P(t) = (1 - F(G))P(t) + NA\gamma \tag{20}$$

Fourth,calculate the value of the decision variable alpha, update the value of NA (t) if the value of alpha is greater than 1 and jump to step 2 where the EV market share r (t) is the value we think we can use the Logistic function to fit the number of charging stations , which we get the following formula:

$$Alpha = \frac{G(t)r(t)\gamma}{Price_{EV}} \tag{21}$$

$$NA(t) = kr(t)A(t) \tag{22}$$

$$r(t) = logistic(N) \tag{23}$$

If the value of α is less than 1, then we think potential consumers in the market are no longer able to purchase electric vehicles, so the market share of electric vehicles will not change. At this moment, we output the proportion of electric vehicles in all vehicles, Compare to determine whether a country can fully convert electric vehicles, while the number of new charging stations each year NA (t) can be proposed for the conversion of the car charging plan. The specific process we also through the following flowchart presented.

$$NA(t) = kr(t)A(t) \tag{24}$$

$$N(t) = N(t-1) + NA(t) \tag{25}$$

$$r(t) = Logistic(N(t)) = \frac{k}{1 + be^{-a}NA(t)} \tag{26}$$

6 A case:the distribution and development plan in South Korea

While the South Korea has already started installing chargers,we aim to continue to expand the number of charging stations in Korea by the number of existing charging stations in Korea. We use the MDM model to comprehensively plan the construction of charging stations for South Korea from the aspects of economy, population, total car sales and so on. The plan includes the increment of charging stations per year and the optimal number of charging stations in each city when Korea fully implements the conversion of electric vehicles and the distribution of charging stations on the traffic network between cities and cities. We have selected 6 cities in South Korea. The figure below shows that the number of charging stations in these 6 cities has risen steadily in the next 60 years and finally reached the optimal number for each city.

you get to start with a clean slate. Present a proposal for evolving the charging network of your chosen country from zero chargers to a full electric-vehicle system. How do you propose the country invest in chargers? Should the country build all city-based chargers first, or all rural chargers, or a mix of both? Will you build the chargers first and hope people buy the cars, or will you build chargers in response to car purchases? What are the key factors that shaped your proposed charging station plan?

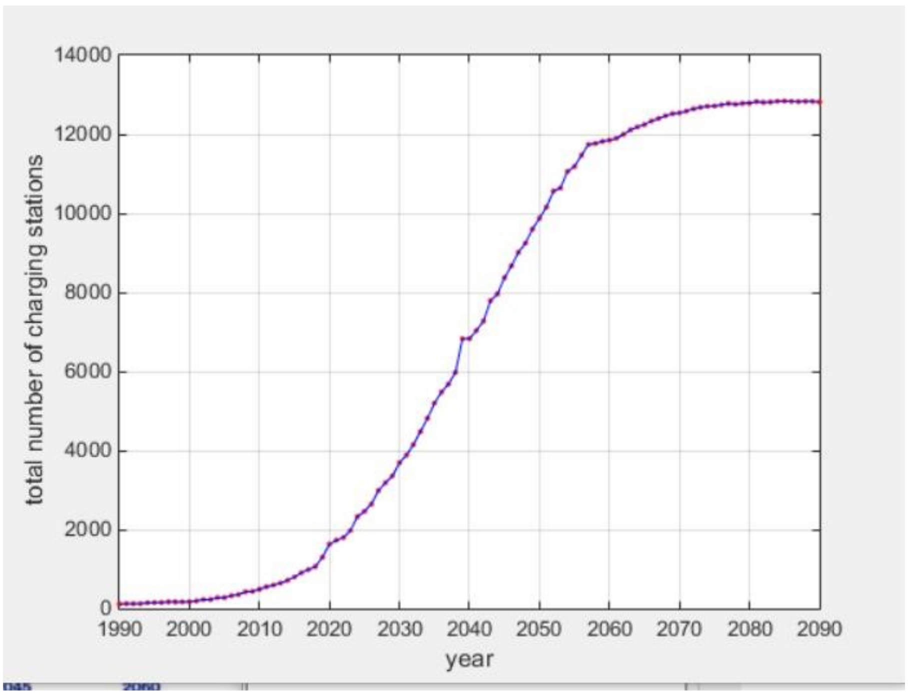

Figure 6: The relation of the number of electric vehicles charging stations and time tin Korean

This figure shows that there will be 72 years for electric vehicles whose occupation rate will be 100%.

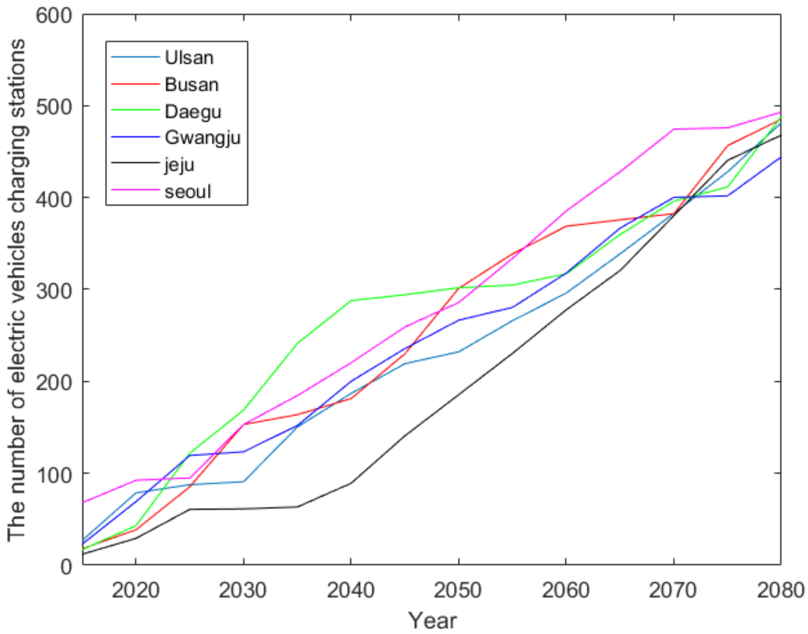

Figure 7: The relation of the number of electric vehicles charging stations and time This figure represents the number of electric vehicles charging stations of six cites in Korean in 62 years

7 Classify growth model towards various countries

Popularizing the electric vehicles and eliminate oil-fueled vehicles is imperative in the world in the future. In order to help various countries successfully migrate away from gasoline and diesel vehicles to all electric cars, we intend to set up a growth plan classification system.

In task2,we have established a multi-stage decision model to decide South KoreaâĂŹs overall growth plan .This is based on the situation of South Korea. But different countries have different characteristics, the growth plan doesnâĂŹt apply to all countries. For different countries, there are different factors that determine the overall growth plan. Now we hope to build a classification system that will help us decide which growth model apply to the specific country.

In order to identify the key factors that lead to different growth networks. First, we select some of the factors that may affect the growth network. we will describe them below. Then, we selected these indicators from 52 countries, we clustered each type of factors, and showed how these classes affected the overall growth plan, and then got three different growth patterns and the key factors triggering the plan. Now we explain the process in detail.

Firstly, we select six possible influencing factors: oil reservation volume, plain proportion, technology level, population distribution wealth distribution, per capita gdp, the

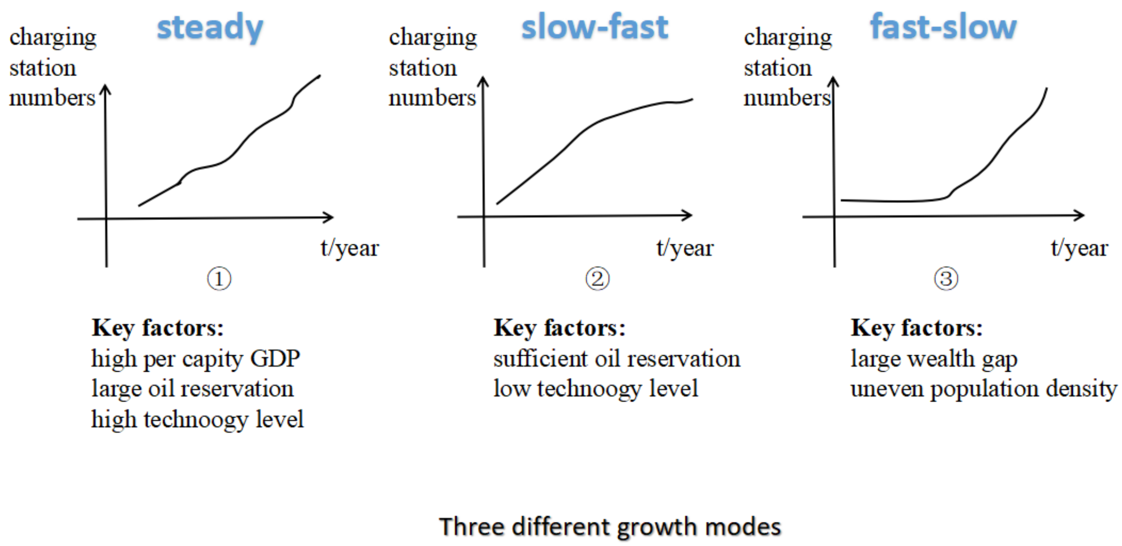

Figure 8: Three different growth modes

area of a country.

Secondly,we collect data from 52 countries and construct a sample set D = x1, x2, ... xm for each type of influence. We divide the sample set into m set: C = C1, C2, ... CM . Calculate the square error:

$$E = \sum_{i=1}^{k} \sum_{x \in C_i} ||x - \mu_i||^2 \tag{27}$$

among them C Is the mean vector, which characterizes the closeness of the mean of the samples. The smaller the value of E, the higher the degree of compaction.

By K-means clustering, we classify these countries into different categories and then get the following classification by analyzing each country's growth network:

- steady: This growth model determined a high ratio of the growth rate of charging stations. High gdp level will enable more people to pay for electric vehicles; High level of science and technology will promote the development of productivity in the region, promote energy development and reduce the cost of charging station construction and so on; Smaller area will cause it takes little time to reach a high level; a larger proportion of plains area will make the popularity of electric vehicles more convenient. In this situation, the development of charging station network has a catalytic role.
- Slow-fast: higher oil content will lower the price ratio of oil and electricity. Such as Saudi Arabia, itâĂŹs oil price is too low to lower peopleâĂŹs desire to buy rechargeable cars because oil prices are lower than electricity prices. It is negative to the development of growth network.
- Fast-slow: Due to the uneven income density, some potential consumers will not be able to buy EV because of their low income level when the network of charging

stations develops to a certain extent, which will cause the charging network to develop slowly. Due to the uneven population density, most of the population in a sparsely populated area is mostly economically backward in a country. Such areas are often unable to popularize electric vehicles more rapidly.

which will have a negative impact on the development of the charging station network in the late stage of development.

Based on the conclusions, we collected data from Australia, China, Indonesia, Saudi Arabia and Singapore and then decided which category they belong to according to the clustering result, and then got its growth mode.

For Saudi Arabia, abundant oil resources cause it to belong to the slow-fast type. For China, uneven income distribution and uneven population density cause it to belong to the fast-slow type. For Singapore, the lower land area cause it to belong to fast type. For Indonesia, lower plain area cause it to belong to fast-slow type. For Australia, the higher gdp and technology cause it to belong to steady type.

Utilizing our model to quantitively analyse the increase of charging stations in Singapore, we obtain the change of total number of charging stations changing with year, as shown in the Figure 9.

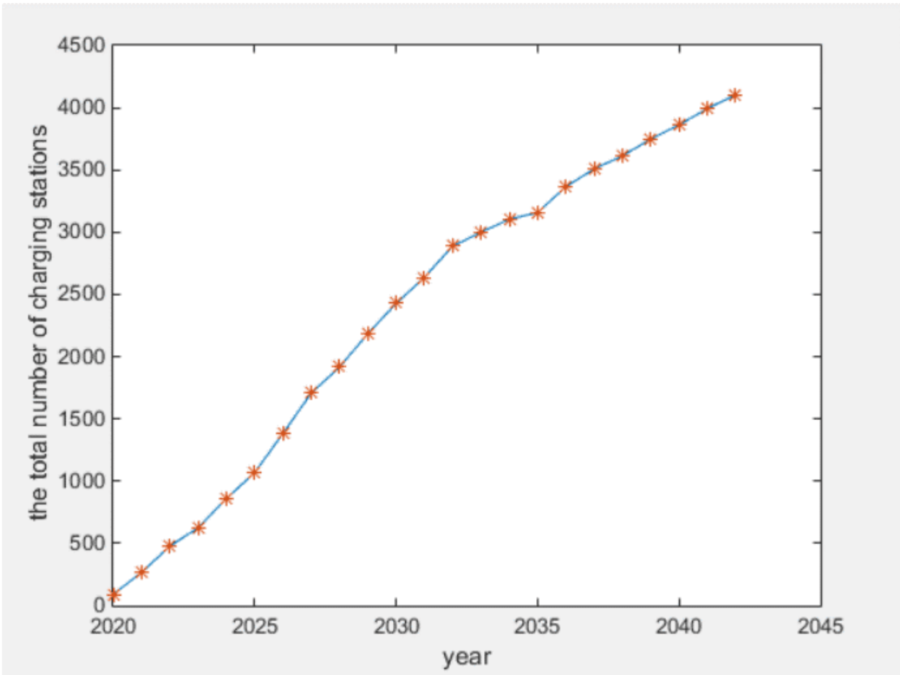

Figure 9: The variance of total number of charging stations changing with year

8 Impact of new emerging technologies

New emerging technologies have rapid advance over past 10 years and it will influence the development of electric vehicles in different degree. We will discuss the impact from car-share services, self-driving cars, rapid battery-swap stations for electric cars, flying cars and a hyperloop on promotion degree of electric vehicles.

Car-share services Car-share services is an innovative form to optimize the allocation of urban transportation resources and improve travel efficiency. It is also an important measure to promote green travel. As the government encourages the use and development of new energy vehicles, it is supported by relevant policies in the layout and construction of the charging stations, so car-share services in various cities is a new energy vehicle. Sharing cars as operating vehicles, whose charging infrastructure can be intensively regulated and constructed. So promoting new energy vehicles has obvious advantages. [16] Therefore, car sharing service is conducive to the further development of electric vehicles.

Self-driving cars The technology combining self-driving and electricity-motivated has exerted larger power than it could be. On MWC 2017, Ford unveiled a new concept of self-driving electric truck, which has the function of sending the goods to some regions vehicles could not cover.[17] Therefore, we could find self-driving will have broad application prospect in the future market, which also can promote the development of electric vehicles.

Rapid battery-swap stations for electric cars Rapid battery-swap stations has high efficiency and good convenience. It only takes just 2 minutes and 46 seconds in replacing a battery, obviously faster than normal charging methods. In addition, battery swap not only can reduce the damage to the power grid in power plants, also can improve the safety of the battery.[18] But construction cost of a battery swap is nearly 10 million yuan. So a wide range of popularity in the short term will be unlikely to achieve. Only by improving the technology and reducing cost, it is likely to make the huge leap in the development process of electric vehicles.

Flying cars and Hyperloop âĂIJPal-V Liberty, the world's first mass-produced flying car, will be unveiled in next month at the Geneva motor show, which will go on sale in 2019 for 3.8 million yuan." [19] "In the future, the high temperature superconducting magnetic train can reach nearly 3,000 km/h."[20] These reports indicate that flying car and Hyperloop have been realized on technology, which will lead huge transformation of traffic modes. However, limited to high price or imperfect realization, we believe it is unlikely to achieve good popularization at initial stage. Long time after, in a highly modern and technological society, large promotion in public may come true. At that time, electric vehicles may have been discarded.

9 Strengths and Weakness

Strengths:

- The proposal put forward by Multi-Stage Decision Model is a dynamic result, which can given the corresponding suggestions according to the change of economy. Unlike other models, we only can supply advice according to fixed time and development trend
- The output is concrete enough to know every specific location of points in the cites.
- The proposal is concrete enough to give some advice from the view of distribution of charging stations, the ratio of supercharging and normal charging and the number of charging stations we plan to construct every year.

Weakness:

- Ignore the influence of electric vehicles on environment, such as the improvement of environment from electric vehicles, which maybe conduce to economy.
- Ignore the loss of discarding vehicles and the rate of elimination.
- The demand points generated by population density diagram from Monte Carol Stimulation maybe have the extreme points, such as at steep, canyon.

10 Handout

Dear guests, ladies and gentlemen,

Hello everyone, I am the leader of South Korea, and it is my great honor to attend this Energy Summit and share with you the development and utilization of new energy.

As we known, with the rapid development of industrialization around the world, the world's energy and climate change, and environmental issues are outstanding, which is the common challenges we face. Urban sustainable development has become the important subject of common concern to the world. Under the condition, it is necessary to develop new energy vehicles and improve fuel combustion efficiency. Among the many new types of energy vehicles, electric vehicles have gained wide popularity among the world countries due to their small pollution. In recent years, to further accelerate the switch to electric vehicles, some countries, including China, have announced that they will ban gasoline and diesel cars In the coming years. From that, I deeply realize that we should have widely promoted the electric vehicles In Korea after I come back to Korea.

At present, the development of electric vehicles in South Korea is serious. Despite the successful construction of more than 500 charging stations in 2017, annual sales of electric vehicles in South Korea rose by 5% in 2017. But at present, the number of charging stations in South Korea is only about 3000 , the distribution of electric cars is very uneven, and the proportion of market share is also declining. The development of electric cars in South Korea has proved unpromising.

Considering the reasons, the technology, per capita income and policy environment for the growth of the electric car has a key role, determine the performance of electric vehicle technology level and quality, also is the main reason that influence consumers to buy. Per capita income means the living standard and affordability of residents. Only when the living standard of residents develops to a certain extent, they will consider buying environment-friendly cars. In addition, the policy subsidy will stimulate the potential consumers to consume ahead of time and promote the development of electric vehicles.

In order to migrate all vehicles to electric vehicles, we predict the its future development: the result shows that growth timeline of electric vehicles. There will be 5,20,31,62 years when occupation rate arrives at 10%,30%,50%,100%. According to the results, at 2023, income under the occasion that building the chargers first is three times of increasing consumers first. Therefore, we make the popularization scheme as follows: building them in cities then mix city-based and rural chargers and confirming gas vehicle-ban date, when it reaches up to 60%.

Above is some ideas about developing electric vehicles and intervention plans for government to take.Thanks for your listening!

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Appendices

```
/*********************************
----------------------------------
Tabu Search Algorithm
----------------------------------
*********************************/
#include "stdafx.h"
#include "stdafx.h"
#include <string>
#include <time.h>
#include <fstream>
#include <iostream>
#include <iterator>
using namespace std;


void initcnf()
{
    printf("\n");
    ifstream in("1.txt");
   for(int i =0;i<n+5;i++)
   {
       for(int j=0;j<=3;j++)
       {
           clause[i][j]=1;
       }
   }
    for (int i = 1; i <= n; i++)
    {
        in >> clause[i][1] >> clause[i][2] >> clause[i][3] >> t;
    }
    /*for(int i=0;i<n;i++)
    {
        for(int j=0;j<l;j++)
        {
            clause[i][j]=rand()%m+1;
        }
```

	the number of destination charging	the number of supercharging
Gyeonggi	462	236
North Chungcheong	524	257
South Chungcheong	435	327
North Jeolla	460	347
South Jeolla	323	237
Gangwon	524	264
North Gyeongsang	405	274
South Gyeongsang	423	284
Ulsan	272	245
Busan	186	137
Daegu	177	158
Gwangju	236	165
jeju	125	82
	4552	3013

	the number of supercharging		the number of supercharging
G-NC	231	SG-NG	244
G-SC	452	SG-Bu	164
G-Ga	343	SG-Ul	194
SC-NJ	424	SG-Da	134
NC-NJ	254	Da-NG	254
NJ-SJ	364	Ul-NG	241
NJ-SG	284	NG-Ga	324
SJ-SG	264		

Figure 10: The distribution of EV charging station in the South Korea

	the number of supercharging	the number of destination charging		the number of supercharging	the number of destination charging	
Alabama	158	30	Mississippi	82	32	67
Alaska	201	25	Missouri	46	27	2
Arizona	167	88	Montana	60	20	44
Arkansas	88	36	Nebraska	116	12	18
California	354	103	Nevada	105	34	559
Colorado	156	96	New Hampshire	160	40	48
Connecticut	234	96	New Jersey	249	76	48
Delaware	60	12	New Mexico	116	30	6
DC	178	14	New York	167	55	7
Florida	302	46	North Carolina	148	28	166
Georgia	94	136	North Dakota	67	24	68
Hawaii	237	46	Ohio	168	130	23
Idaho	110	42	Oklahoma	94	26	21
Illinois	160	89	Oregon	167	58	101
Indiana	332	66	Pennsylvania	130	64	33
Iowa	206	24	Rhode Island	158	45	12
Kansas	324	44	South Carolina	367	68	22
Kentucky	126	36	South Dakota	44	12	18
Louisiana	135	40	Tennessee	264	46	20
Maine	106	18	Texas	276	56	9
Maryland	58	24	Utah	264	28	71
Massachusetts	135	75	Vermont	320	16	62
Michigan	47	86	Virginia	275	49	206
Minnesota	85	50	Washington	168	34	25
Wisconsin	356	70	West Virginia	120	18	
Wyoming	74	2				

Figure 11: The distribution of urben EV charging station in the United States

	the number of supercharging		the number of supercharging		the number of supercharging
WA-OR	25	OK-AR	25	VI-NO	14
WA-MT	16	AR-LO	65	NO-SOU	24
WA-ID	37	LO-TE	32	SOU-GE	8
OR-CA	46	LO-MI	45		
OR-ID	49	AR-MI	13		
ID-MO	58	MI-IO	25		
ID-WY	27	IO-IL	14		
ID-UT	23	IO-WI	19		
CA-NE	25	IO-MIN	34		
CA-AR	65	MIN-WI	32		
AR-UT	42	WI-IL	23		
AR-NE	16	IL-TEN	12		
UT-ID	6	TEN-MIS	26		
UT-CO	25	TEN-GE	24		
UT-WY	2	GE-AL	20		
WY-MO	45	GE-PL	16		
WY-NE	16	GE-SO	20		
WY-SO	35	SO-NO	27		
WY-NO	16	NO-VI	32		
NE-TE	46	VI-WE	35		
CO-KA	37	WE-DH	19		
NO-SO	29	WE-RE	32		
NO-MI	28	DH-MIC	35		
SO-NE	65	RE-NEW	42		
SO-KA	24	REE-NEWJ	25		
NE-KA	13	RE-DEL	36		
KA-OK	42	RE-MAR	37		
KA-MI	25	RE-VI	29		
	883		794		46

Figure 12: The distribution of rural EV charging station in the United States

```
    }*/
    for(int i=1; i<=n; i++)
        for(int j=1; j <= l; j++)
    {
        //sign[i] == clause[i][j]/abs(clause[i][j]);
        if(clause[i][j]/abs(clause[i][j]) == 1)
            sign[i]=1;
        else
            sign[i]=0;
    }

    for(int i=1;i<=m;i++)
    {
        iteration_age[i]=0;
    }
    for(int i=0;i<=N;i++)
    {
        SVS[i]=0;
    }
}

int v_cnf(int var[])
{
    int v=0;
    for(int i=1;i<=n;i++)
    {
        vclause[i]=1;
    }
    for(int i=1;i<=n;i++)
    {
        for(int j=1;j<=l;j++)
        {
```

```
            vclause[i] *= (sign[3*(i-1)+j]^var[abs(clause[i][j])]);
        }
        v+=vclause[i];
    }
    return v;
}

int candidate(int a)
{   int var1[m+1];
     //memcpy(var1,variable,m+1);
    for (int t = 0; t < m+1; t++)
        var1[t] = variable[t];
    int v=0;
    //v=v_cnf();
    var1[SVS[a]]=1-var1[SVS[a]];
    v=v_cnf(var1);
    return v;
}
void tssat()
{

    srand(double(time(NULL)));
    for(int i=1;i<=m;i++)
    {
        variable[i]=rand()%2;
    for(int i=1;i<=m;i++)
    {
        printf("%d ",variable[i]);
    }
    initcnf();
    int iteration=1;
    int flips=1;
    int c=v_cnf(variable);
    printf("\n");

    while(v_cnf(variable)!=0&&iteration < itera_max)
    {   int a=0;
        for(int i=0;i<n;i++)
        {
            if(vclause[i]==1)
            {   int svs=abs(clause[i][rand()%l]);
                SVS[a]=svs;
                int pos = 1;
                for(int i=0;i<a;i++)
            {
                if(SVS[a]==SVS[i])
                {
                    pos = 0;
                    break;
                }
            }
                if (pos == 1)
                {
                a++;
                }
            }

        int flag=1;
        int s=0;
        while(s<a&&flag==1)
        {
```

```
            for(int j=s+1;j<a;j++)
            {
                if((candidate(j)-v_cnf(variable))<(candidate(s)-v_cnf(variable)))
                {
                    /*int temp=candidate(i);
                    candidate(i)=candidate(j);
                    candidate(j)=temp;*/
                    int temp=SVS[s];
                    SVS[s]=SVS[j];
                    SVS[j]=temp;
                }
            }
            if(iteration_age[SVS[s]]+L>=iteration)
            {
                if(candidate(s)-v_cnf(variable)<0)
                {
                    variable[SVS[s]]=1-variable[SVS[s]];
                    iteration_age[SVS[s]]=iteration;
                    flag=0;
                    flips++;
                }
                else
                {

                    //flag=0;
                    s++;
                }
            }
            else
            {
                variable[SVS[s]]=1-variable[SVS[s]];
                iteration_age[SVS[s]]=iteration;
                flips++;
                flag=0;
            }
        }
        iteration++;
    }
    for(int i=0;i<m;i++)
    {
        printf("%d ",variable[i]);
    }
    printf("\n");
    int v=v_cnf(variable);
    }
}

int _tmain(int argc, _TCHAR* argv[])
{   time_t start,end;
    start = clock();
    tssat();
    end = clock();
    system("pause");
    return 0;
    return 0;
}



/*********************************
```

```
-----------------------------------
k-means clustering
-----------------------------------
*********************************/
def kMeans(dataSet, k, distMeas=distEclud, createCent=randCent):
    m = shape(dataSet)[0]
    clusterAssment = mat(zeros((m,2)))
    centroids = createCent(dataSet, k)
    clusterChanged = True
    while clusterChanged:
        clusterChanged = False
        for i in range(m):
            minDist = inf; minIndex = -1
            for j in range(k):
                distJI = distMeas(centroids[j,:],dataSet[i,:])
                if distJI < minDist:
                    minDist = distJI; minIndex = j
            if clusterAssment[i,0] != minIndex: clusterChanged = True
            clusterAssment[i,:] = minIndex,minDist**2
        print centroids
        for cent in range(k):
            ptsInClust = dataSet[nonzero(clusterAssment[:,0].A==cent)[0]]
            centroids[cent,:] = mean(ptsInClust, axis=0)
    return centroids, clusterAssment
```