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2018 MCM/ICM Summary Sheet
(Your team's summary should be included as the first page of your electronic submission.)

All-Electric Vehicle Will Be a Reality

Summary

For the sake of the rapid advancement of electric vehicles, it is of great necessity to establish suitable charging stations to meet the demand for electric vehicles by all means. In comprehensive comparison with several charging modes, we only consider building a fast-charging location.

We deem that the ideal amount of charging stations is the ratio of the number of vehicles whose battery has used up to the maximum number of vehicles can be served each station simultaneously. Identically, the ideal quantity of charging stations equals the number of charged piles plus the number of acceptable queuing vehicles. When the ratio of the existing charging station to the desired number is higher than the threshold, we believe that electric vehicles industry is on the right track. Now it turned out that the ratio of the amount of charging stations to the ideal number in the U.S. is 0.904, which demonstrates congestion will occur when charging at peak times. Hence, we can draw a conclusion naturally that it is basically on track currently, but still needs further optimization. Furthermore, we set up different proportionality coefficients for cities, suburbs, and rural areas to obtain the ideal amount of the charging stations.

To determine the amount and address of the charging stations what we will build in the city, we created to develop the location-sizing model. Besides, with a greedy algorithm and genetic algorithm, taking Uruguay as an example, we determine the quantity of electric vehicles in the city by simulation. As a result, the number of electric vehicles needed in suburban and rural areas according to the proportionality coefficient.

We think there is a linear relationship between the amount of electric vehicles and the population. Therefore, the logistic model is built to predict the amount of electric vehicles in Uruguay. By giving the number of electric vehicles, we will figure out the time it takes to achieve the target quantity. As a consequence, we make a development plan with a cycle of ten years.

We analyze the terrain, the population, and the wealth respectively. The population density affects the service vehicles of individual stations, thus indirectly affecting the number of ideal charging stations. Wealth will directly affect the ideal number of charging stations, and geographical location affects the construction circle of the charging stations. Then we divided the country into five categories and discussed how to set down the development plan respectively for the sake of boosting its advancement.

Owing to the technological progress, whose development has increased rapidly beyond our wildest imagination. In the meantime, other new vehicles also hinder the overall development of electric vehicles. We have established five standards of price, convenience, vehicle utilization, speed and environmental protection and evaluated the influence degree by 3 orders of magnitude. In consequence, we also analyzed the impact of the innovation of new vehicles on the development plan of the electric vehicles.

Keywords: charging stations, location-sizing model, genetic algorithm

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1. Introduction

1.1 Restatement of the Problem

With the influence of resources, environment and financial crisis, the various countries around the world have accelerated the advancement of developing new energy vehicles. They designed it as an effective way to solve energy crisis and environment pollution. In order to accelerate the conversion process of fuel vehicles to electric vehicles, we need to establish sufficient charging stations to be used available. The key factor that affects the construction plan of charging stations is the convenience of charging stations, that is to get the charging service in time.

Most of the existing charging stations now are fast-charging and destination charging location. Moreover, considering that destination charging locations are built in private places, which is inconvenient. Hence, everyone should be given a convenient, equal opportunity to charge so that Tesla gets on scale in the U.S. So, we only consider public, fast-charging locations serving the general public. Electric cars replaced fuel vehicles which will not happen overnight. In addition to the amount and location of the charging stations, we also need to forecast charging vehicles along with the growth of the time trend. And we develop a development plan according to the urban, rural, suburban, problem such as population distribution. As a consequence, we mainly concern the following questions:

- Analyze whether Tesla gets on track in the U.S.
- Determine the optimal quantity and location of charging stations distributed in Uruguay by taking Uruguay as an example.
- Consider the charging stations changes over time.
- Consider the influence of population on geographical location, population and wealth respectively.
- Evaluate the impact of different vehicles on the trend of electric vehicles growth.

1.2 Previous Research

For the network construction of charging facilities, the location of charging stations and the number of charging devices provided directly affect the service quality and operating efficiency of the charging stations in the later stage. Based on the research of station selection problem, charging construction can be divided into charging station construction based on path demand and point-based demand. By comparison with the theoretical model of charging station queuing, we study the location and sizing problem of under different demand modes.

By analyzing the possible problems in the operation planning of charging facilities under market conditions, and the development prospects of several charging modes in the market are contrasted. We put forward some suggestions including charging facility information platform, vehicle battery recycling network, emergency service system and charging service setup which included other service systems. As a result, we improve the charging facility architecture.

At present, although the support of government departments and some automobile manufacturers on electric vehicles is of great and the sales of electric vehicles are still not satisfactory, it is critical to study the consumers' willingness of pursuing electric vehicles and their influencing factors.

1.3. Our Work and Some Explanation to the Problem

- Convenience is a key factor in development.

When developing electric vehicles at the beginning, environmental protection is to attract consumers to buy electric vehicles. As the basis of our charging infrastructure is increasingly perfect, which bring more convenience to electric vehicle charging. It is the key to our comprehensive development of electric vehicles.

- Analyze whether Tesla gets on track in the U.S.

We define the ratio of the number of existing charging stations to the number of ideal charging stations, and when the ratio is above the threshold, we are on the right track. The number of ideal charging stations is equal to the ratio of vehicles with charging needs to the number of vehicles simultaneously served by a single station, and the number of vehicles simultaneously served by a single station is related to individual tolerance. Tolerance is defined as the front-queued vehicle that we can endure.

- Determine the location and number of charging stations in Uruguay.

We divide the city into cities network, and the charging station candidate points lie in the network node. We determine the location and number of charging stations in the city within a range of time that people can tolerate. Response time is equal to running time plus queuing time and service time. Then determine the city's charging station demand coefficient, the city will be allocated by the total number of ideal charging stations. Then the other two different demand coefficient of the areas are assigned to charging stations.

- Consider the charging stations changes over time.

We found a linear relationship between the growth of electric vehicles and population growth, so we can predict the development of electric vehicles in Uruguay through the development of electric vehicles in the U.S.

- Evaluate the impact of different vehicles on the trend of electric vehicles growth.

We identified five factors that affect the development of electric vehicles and quantified them with Likert scale. Then we evaluated the new tools according to different orders of magnitude. Finally, we qualitatively analyze its impact on development plans of the electric vehicles.

2. Assumption

- The country's current total car volume has reached saturation
- The charge demand for the car is fixed every day
- The city road is network, and the charging station is built at the network node

3. Symbols and Definitions

Symbols	Definitions
S	The number of all electric cars
Z	The number of charging stations that we need
γ	The proportion of cars with charging needs
K	People's ability to endure
α	The maximum number of services for a charging station
m	The number of existing charging stations
β	Account for the total number of charging stations

4. The Model

4.1 The Principle of Selecting the Station

Tesla, an American company, specializes in electric vehicles and for the formally driving's sake, there are presently two types of charging station formally opened to put into service:

- **Destination Charging Location**

  Providing a charging service with a few hours or even overnight mainly for chargers which built in private fields including hotels, restaurants and shopping center across the country, however, it merely available for people catching the lowest threshold of consumption in these fields.

- **Fast-Charging Location**

  Being in the service of long-distance journey, Tesla launched the "Supercharging Location" Network, the national public common properties, provides up to 170 miles of limitary distance and a full charge in around 30 minutes as by serving to citizens.

In our daily life, "Destination Charging Location" is installed in private places such as homes and companies, which can meet the travel conditions of daily life on a charge. As a vehicle, the purpose of the vehicles is running on the road. During a long journey, if a destination charging location arranged along the road, the time of charging will reduce the efficiency of getting around. Moreover, considering that destination charging locations are built in private places, which is inconvenient. Hence, everyone should be given a convenient, equal opportunity to charge so that Tesla gets on scale in the U.S. So, we only consider public, fast-charging locations serving the general public.

4.2 Establishment of the Station

Fuel and diesel vehicles were replaced by all-electric vehicles on scale in the US come true demonstrates that the quantities of charging station can meet the energy consumption of all electric vehicles. The number of charging stations is calculated by means of the ratio of the amount of all electric vehicles to those can be serviced in a charging station.

$$\frac{\gamma \cdot S_1}{\alpha} = Z_1 \qquad (1)$$

- S_1 is the number of electric vehicles whose batteries need to be charged at the same time in the U.S.
- γ is the percentage of vehicles needed to be daily charged.
- α is the maximum servicing number of electric vehicles a charging station offers.
- Z_1 is the number of charging stations can satisfy the need of electric vehicle

We creatively put forward the definition of "Endurable Degree" of k which means the tolerable quantity of vehicles queuing for battery charging in front of when all charging piles in the charging stations used. To determine the product of a and k, we define "the largest amounts of electric vehicles a charging station" as α. By the virtue of different policies, social conditions, humanistic environment and personalities in the state are not as the same as those in other fields, on this account, neither the "Endurable Degree" is. And we call it k. In consequence, the quantity of electric vehicles a charging station serves:

$$\alpha = ka \quad (k>1) \qquad (2)$$

So, we can figure out the numbers of charging stations needed. Further, we suppose m as the number of existing charging stations currently.

- m > Z_1, the electric vehicles industry can get on track.
- m < Z_1, only if the electric vehicles industry adds to new stations or develop newly charging technology can the number of vehicles from every station gave the service increase.
- m = Z_1, in order to facilitate the citizens' use, we can increase new stations, considering the damaged charging files may exist.

After collecting information, we have drawn the conclusion that the number of existing electric vehicles is about 300,000, but fast-charging locations are used only about 10% of the total, in the region of 30,000. Now the United States has 1,130 stations and 8,496 charging piles, with about eight charging piles per station. If we suppose k is 3/2, the number of electric vehicles a station called α is 12 and Z_1 is about 1250. Owing to the inequality "m < Z_1", it is not enough to ensure all electric vehicles to get on track.

4.3 Distribution in Different Places

Supposing all American citizens in the U.S. decided to use electric vehicles instead of fuel vehicles, we could divide American regions into cities, rural and suburban 3 pieces for the sake of economy and rationality and rearrange the layout of the charging stations. Hence, we have the equations below:

$$\frac{\gamma \cdot S_2}{\alpha} = Z_2 \tag{3}$$

where our interpretations are:

- S_2 is the total number of electric vehicles when all electric vehicles used by all the citizens.
- Z_2 is the number of charging stations needed.

In order to entirely replace all fuel vehicles, the total number of electric vehicles is the sum of the number of existing fuel vehicles and the number of existing electric vehicles. In this process, the total number of electric vehicles when all electric vehicles used by all the citizens is:

$$S_2 = S_1 + S_3 \tag{4}$$

- S_3 is the number of existing fuel vehicles.

We set the distribution proportionality coefficient of the station in the city as β_1, the station of the rural area as β_2, and the station in the suburbs as β_3. We use the control variable method to describe the distribution of charging stations in three different regions. Apparently, when taking into account economic development, cultural level, environmental awareness and other issues, the number of charging stations in cities that are larger than the number of charging stations in rural areas which is larger than the number of charging stations in the suburbs:

$$\beta_1 > \beta_2 > \beta_3 \tag{5}$$

Set the city site distribution ratio coefficient a is known. But the value of b and c can be valued at random but must be less than a. When the number of charging stations that can meet the operation of electric vehicles in the U.S. is known in the region of 2.5 million. We take 1 as the x-axis and 2 as the y-axis and c, the number of charging stations will be built in the city as the z-axis. We take the value of a is 5, b is between 1 and 4, and c is between 1 and 3. The number of charging stations in cities is:

$$Z_3 = Z_2 \cdot \left(1 - \frac{\beta_2 + \beta_3}{\beta_1 + \beta_2 + \beta_3}\right) \tag{6}$$

We draw the three-dimensional picture below:

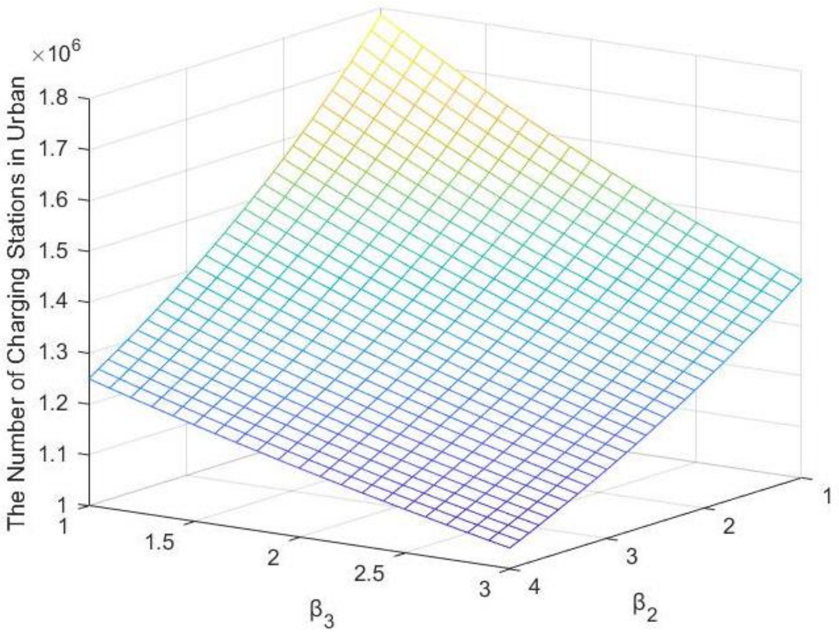


Figure. 1

As it shown in **Figure.1**, when we know the proportion coefficient of a certain area or the amount of the charging station, we can adjust our allocation plan according to the changes of proportion of another two areas in order that we will achieve reasonable distribution of charging stations.

4.4 Development of Uruguayan Electric Vehicles

We took Uruguay for example. Owing to the small territory of Uruguay and the limited operating range of the electric vehicles, Uruguay is suitable for developing electric vehicles industry. Countries from all around the world are developing new energy vehicles, meanwhile, Uruguay has also increased its input in the field of electric vehicles industry. In order to migrate all their personal passenger vehicles to all-electric vehicles instantaneously in Uruguay, we can reasonably establish the number of the charging stations and determine the optimal location and distribution of the charging stations. We assume that the budget for building a charging station at this time has already set down. The above problems can be easily transformed into location-sizing of charging stations. Our goal is to determine the address of the city charging stations and the number of charging piles called a which is equipped in the stations so that the maximum number of the electric vehicles that each station receives charging service has the highest expected value.

Assuming that everyone in the same country has the same tolerance, degree called k. When a and k are determined, the number of all charging stations can be calculated. We fixed the city's coefficient of proportionality by the control variable method from the task 1 and adjusted the coefficient of proportionality of another two regions to allocate the charging stations.

4.4.1 Location and Sizing-Model in the City

We develop the model to determine the number and location of charging stations in the city. The city is divided into a network and the candidate points are on the network node. Assuming that the electric vehicle with charging needs to select the nearest charging station for service. In combination with queuing theory, we introduce the response time which is defined as the running time from the points where the vehicles needed to charge to the charging stations and the time staying in the station.

The goal of our model whose decision variables are the choice decision and the sizing-decision is to determine the address of the charging stations in the city and the number of corresponding charging piles in the station.

Due to limited budgetary costs, if you choose to build multiple charging stations, the number of corresponding charging piles will be reduced. Although excessive charging stations reduce the running time from the points where the vehicles needed to charge to the charging station, it will increase the waiting time in the charging stations. In comparison, if you choose to have more charging piles in a charging station, the number of charging stations you can choose to build will decrease. Although excessive charging piles reduce the queuing time in the charging stations, it will also increase the running time from the points where the vehicles needed to charge to the charging stations. Therefore, we set up a location and sizing-model to ensure two decision variables optimally.

The parameters used in the model are defined as follows:

- N is a collection of demand points, $\mathrm{N} = \{n|1, \dots, i\}$; M as a collection of candidate points, $\mathrm{M} = \{m|1, \dots, j\}$;
- d_n represents the demand at the demand point n; Poisson distribution obeying the parameter λ_n;
- s_{nm} represents the running time of demand point n to the charging station m; t_{nm} represents the response time from demand point n to the charging station m;
- T is the maximum tolerable response time; w_m is the average stay at the charging station m;
- c_m is the cost of building a charging station at the candidate point k; c_0 is the cost of a single charging pile plus installation costs.
- Q is the total budget of the charging station construction; v is the average service rate of a charging pile;
- λ_m is the ratio of the electric vehicles reaching the charging station m; λ_n is the ratio of the electric vehicles reaching the demand point n;
- b_m is the number of charging piles installed on the charging station m;
- $x_m = \begin{cases} 1 & At\ m\ point\ to\ establish\ the\ charging\ station \\ 0 & others \end{cases}$
- $x_{nm} = \begin{cases} 1 & Point\ m\ provides\ charging\ service\ for\ point\ n \\ 0 & others \end{cases}$

According to the definition, we set up the following model:
Objective function:

$$\max \mathrm{Z} = \mathrm{E}(\textstyle\sum_{n\in N}\sum_{m\in M}(d_n \cdot x_{nm}P(t_{nm} \le T))) \quad (7)$$

$$\text{s.t.}\begin{cases} x_{nm} \le x_m \text{ , } \forall m \in M \text{ , } n \in N & (8) \\ \sum\limits_{m\in M} x_{nm} = 1 \text{ , } \forall n \in N & (9) \\ b_m \le U x_m \text{ , } \forall m \in M \text{ , } U \sim \infty & (10) \\ \sum\limits_{j\in M|d_{nj}\le d_{nm}} x_{nj} \ge x_m & (11) \\ \sum\limits_{m\in M}(c_m + c_0 b_m) \le Q & (12) \\ t_{nm} = s_{nm} + w_m & (13) \\ \lambda_m = \sum\limits_{n\in N}\lambda_n x_{nm} & (14) \\ \lambda_m < v b_m & (15) \\ x_m, x_{nm} \in \{0,1\} & (16) \\ b_m \in N^+ & (17) \end{cases}$$

Among them, the objective function (7) the expected value of the system to deal with the charge demand when the response time does not exceed a given time range. P is the corresponding probability; constraints (8) prevent charging demands from being allocated to candidates without the charging stations; (9) ensures that the charging demands from a charging point can only be met by a charging station; (10) rules that only if the charging piles is installed at m can the charging piles installed on the charging stations;(11) ensures that the charging demand generated by each demand point is received at the nearest charging stations;(12) the total cost of the network construction of the charging stations does not exceed the budget cost;(13) represents that the response time is equal to the running time of a demand point to a charging station plus the time of stay.(14) represents the relationship between the probability of a successful charging of an electric vehicle arriving at a charging station and the rate of charging demands at each demand point;(15) ensure the stability of the system and avoid queuing for a long time.

4.4.2 The Solution of the Model

This model is a NP problem, and it is rather difficult to figure it out. We first decompose the model into two sub-models: the first sub-model determines the location of the charging stations and the second model determines the number of charging piles in a charging station.

According to the queuing theory, we assume that $(T_{nm} = T - s_{nm})$, then the objective function will be translated into:

$$\max Z = E(\textstyle\sum_{n\in N}\sum_{m\in M}(d_n \cdot x_{nm}F(T_{nm}))) \quad (16)$$

$F(T_{nm})$ represents the probability distribution function of the time of an electric vehicle staying at a charging station.

First, the genetic algorithm is used to solve the location of charging stations. The steps of the solution are as follows:

- **Coding**

First of all, we code the charging stations and use the 0-1 code, of which 1 represented the construction of charging station in the corresponding location, 0 represents the corresponding location did not build the charging station. The coding bits were | M |, which represents the number of candidate charging stations.

- **Fitness Function**

To get the optimal number and location of the charging stations, we choose the objective function as the fitness function, that is, the maximum expected value of the charging demands charged by the charging stations.

- **Crossover and Mutation**

The crossover operation uses a single point crossover, randomly selects a chromosome, and selects the mutation point according to a certain mutation rate for mutation.

- **Selection**

The individuals who choose the maximum value of the objective function value in the parent and progeny population evolve to the next generation, which ensures that the good characteristics are preserved.

Second, we use greedy algorithm to solve the optimal charge pile allocation problem. Given is the address of the charging station is set S, and S is contained in K. The algorithm steps are as follows:

Step 1: Calculate the average charging demand rate of M for each charging station is λ_m;

Step 2: Calculate the number of charging piles installed on the selected charging station, $b_m = \frac{\lambda_m}{v}$;

Step 3: If $\sum_{m\in S}(c_m + c_0 b_m) > Q$, that is no solution, end; If $\mathrm{Q} - \mathrm{q} < \sum_{m\in S}(c_m + c_0 b_m) \le Q$; that is, b_m is the result of the distribution of the charging piles, otherwise, take the fourth step.

Step 4: If $\sum_{m\in S}(c_m + c_0 b_m) \le Q - q$, allocate the remaining charging piles and add one charging pile to each charging station and calculate the increment of target value when one charging pile is added at each charging station, that is:

$$\Delta \mathrm{m} = \sum_{m\in M} \lambda_m (F(T_{nm+1}) - F(T_{nm})) \tag{17}$$

The charging pile is allocated to the largest charging stations with $\Delta \mathrm{m}$ value and

assume that: $b_m = b_m + 1$; repeat the fourth step until all the charge pile methods are allocated.
The flow chart of the algorithm is as follows:

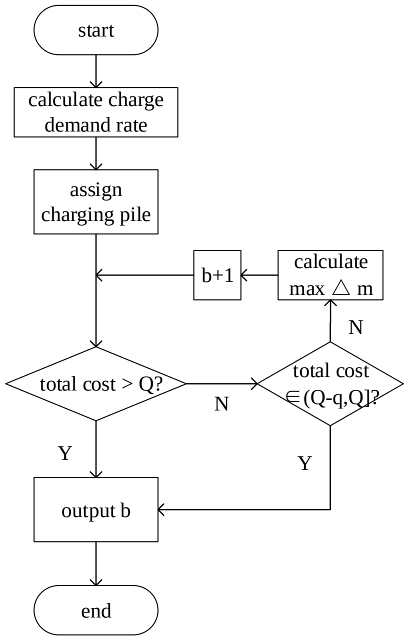


Figure 2. Greedy Algorithm Flow hart

We use the MATLAB to simulate the 25 points on the 5*5 plane. Assume that all demand points are charging station candidate, that is 25 candidate points. The average charging demand of each demand point is randomly generated in the [10,20] interval and the location cost of each point is randomly generated in the [10,30] interval. The cost-plus installation cost of a single charge pile is 5, and the maximum tolerance response time is 0.5. Finally, the position number of the charging stations and the number of the charging stations are calculated.

When designing the genetic algorithm, the corresponding parameters are set as: the population size is 25, the cross rate is 0.8, the mutation rate is 0.02, the evolutionary algebra is 100.

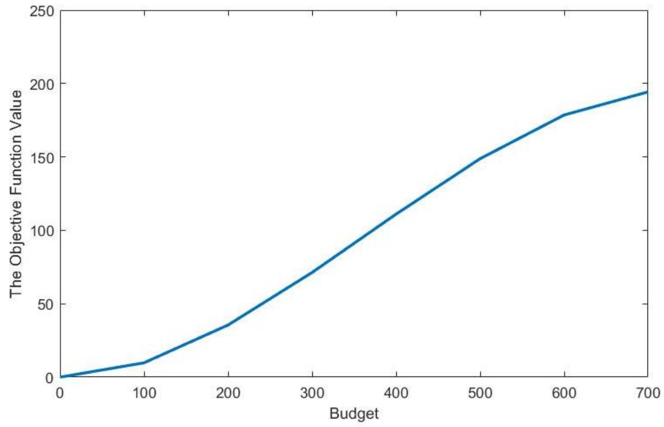
The results calculated are as follows:

Table 1. Analog charging station location

Number	1	2	3	4	5
1	1	0	0	1	1
2	1	1	1	0	1
3	0	0	0	1	0
4	1	0	1	0	0
5	0	1	1	1	0

4.4.3 Sensitivity Analysis

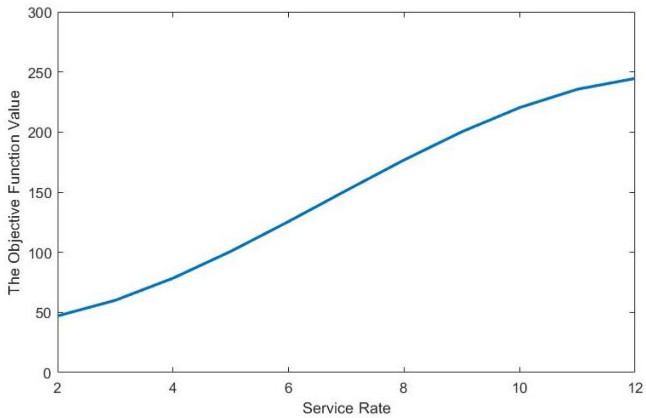
We set the service rate of a single charging pile to 8. By giving a different value for the budget, we get a different value of the target function, and the relationship is shown in the figure.



According to the results, we can learn that as the cost of the budget increases, the number of rechargeable charging stations and charging piles can be increased, so the target function is also increased. That is, the more the average demand for the system to complete the charging service within the specified time.

But because of the uncertain total amount of demand, there is no limit on the value of the target function. As a consequence, when the demand for charging is saturated and the cost of the budget is increasing, the demand for electric vehicles will grow smaller and smaller.

When we confirm the budgetary cost, we set it to 600. By giving different average service rates, we get the relationship between the average service rate of charging piles and the objective function value.



From the graph, we can see that with the increase of service rate, the average charging demand of charging piles in unit time increases, and the number of charging piles needed to be charged in the charging stations is reduced, and the number of charging stations buildable can be increased. As a result, more charging stations can serve more electric vehicles, and the more the average demand for charging services is completed within the prescribed time. But when the rate is large enough, the target function is also saturated when the charging time of the electric vehicles can be ignored.

5. Key Factors of the Plan

When we know the location of candidate points, we can find out the optimal number and location of charging stations based on the above algorithm. Since all vehicles in Uruguay are converted to electric vehicles, the total number of vehicles in Uruguay equals approximately the total number of electric vehicles. Convenience is one of the most important factors in the plan for the all-electric vehicles in Uruguay. Therefore, the result of our solution must meet this condition.

The key to the entire charging station system is the average service rate of the charging piles at each site. When the rate is faster, the average stay time of each person at the charging stations will be reduced, thereby the response time will also decrease and this will make people feel great convenience. Accordingly, when we are to develop all the electric vehicles to replace the traditional vehicles, how to improve the improving efficiency should be given priority. Only if the charging technology is improved and the speed is accelerated, can the traditional vehicles be completely replaced by the electric vehicles.

6. Investigation of All-Electric

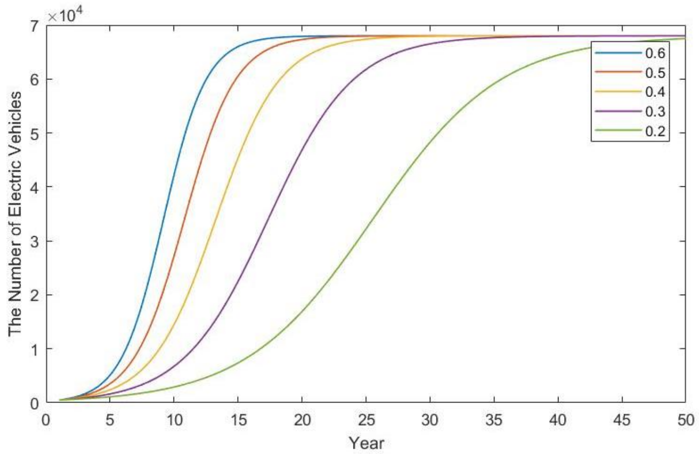
Uruguay, located in America, whose terrain, policies, and people's awareness of environmental protection are similar to that of the United States. We assume that the development plan of Uruguay electric vehicle is also similar to the development of Tesla electric vehicle in the U.S. On this account, we used the sales of Tesla in the United States in recent years to predict Uruguay's development plan.

We think that the development of electric cars is similar to the population growth, that is, the logistic model. We calculate the growth rate of 0.5 according to the sales of Tesla. According to the formula of logistic, so we think the growth rate of electric cars in Uruguay is near 0.5.

$$\mathrm{x(t)} = \frac{x_m}{1+(\frac{x_m}{x_0}-1)e^{-r(t-t_0)}} \tag{18}$$

$x_m$are all of the cars, and R is the growth rate.

We got 680 thousand cars in Uruguay, so we have the following growth curve.



We found that when the growth rate is 0.3, the development of electric vehicles is in line with the trend of scientific and technological development. According to this trend, we have made the following plans:

Table 2. Distribution Change

Electric Car Ratio	Subsidy	Infrastructure	Prohibit the Car	Plan year
0	0	10%	0	2
30%	10%	40%	30%	13
50%	5%	60%	50%	16
70%	1%	80%	70%	20
100%.	0	100%	100%	30

Table2 means a plan for the transition from 0% to 100% of the state's electric vehicle is expressed. Among them, subsidy represents the state's compensation amount when purchasing electric vehicles. Infrastructure indicates the degree of construction of electric vehicle charging stations. Prohibit the car indicates the extent of the prohibition of fuel vehicles when the government is implementing electric vehicles.

In the mid stage of development, infrastructure construction has been basically completed, and the technology is developing slowly, so the electric car prices began to show the advantages. The government should reduce subsidies, and improve the construction of infrastructure. Then they began to layout in suburban and rural areas, and the implementation of the ban of the vehicle. In order to improve the level of use of electric the car better, we attract more people to buy electric cars.

In the late stages of development, the cars were completely banned and all motorized in urban, suburban and rural areas. At this point, the government does not have to subsidize electric cars and even start to make a profit.

6.1 The Influence of Different Factors

The key factor in our development is convenience, and we are considering that more factors may have an impact on our plans. We will put the geographical location of all countries, population density distributions, wealth distributions into the analysis.

We divide the geographical situation into four aspects: flat ground, ocean, desert, and hill. Our electric vehicle station is mainly built on flat land. If the terrain of the country is mainly flat, then our investment and construction plan is implemented normally. If we build a charging station on other terrain, it will be inconvenient to drive the car. Our investment plan needs to be changed.

The area which the population is density will result in the queue time increases. It will make people feel not convenient. Single station service vehicles will be reduced, so we must increase the charging station number, so as to meet the demand of charging in densely populated areas. The construction of more charging stations will delay our charging station construction plan. We compared to the normal development plan, the country with a large population density should have a longer charging station construction cycle, and there should be more charging stations.

We divide the wealth into developed countries, developing countries and underdeveloped countries. The investment plans of developed and developing countries will not change, and the plans of the underdeveloped countries will be adjusted. Because people in the underdeveloped countries do not have enough economic strength to develop environmental protection, our electric cars cannot be popularized.

Based on the above conditions, if a country has more than one condition, the feasibility of our development will be affected. We need to change our investment strategy. We divide these countries into five parts: the geographical conditions are not satisfied, the wealth is not satisfied, the population is not satisfied, and the three conditions are not satisfied.

If the condition is not satisfied, we need to develop for more than 30 years. If the terrain conditions are not satisfied, the country needs to help improve the road conditions and build an electric vehicle station. Economically underdeveloped countries need to subsidize more money and spend more time. If both are not satisfied, it is necessary to improve both the terrain and the subsidy.

6.2 Development under technology

With the improvement of the city level, the pressure of traffic is increasing, and the harmful substances such as tail gas and other harmful substances lead to the pollution of our living environment. In order to improve this problem, the state has decided to gradually ban fuel vehicles, so the new type of transportation is undoubtedly the best choice in the future. The emergence of a variety of vehicles will have a certain impact on the demand for people to buy electric cars.

We will evaluate the following new means of transportation from price, convenience, vehicle utilization, speed, and environmental protection.

Table3. Comparison of Five Kinds of Transportation

Transportation	Price	Convenience	Utilization ratio	Speed	Environmental protection degree
Electric cars	2	2	3	2	2
Car-share	1	2	3	2	3
Ride-share	1	1	3	2	3
Self-driving cars	2	1	3	2	2
Flying cars	3	1	2	3	3
Hyperloop	3	1	2	3	2

We definite 1, 2, and 3 represent 3 kinds. 1 is the lowest level, and the 3 order is the highest.

The price indicates the cost required for the use of the vehicle. Convenience indicates that it is easy to use the means of transportation. The utilization rate represents the frequency and speed means the speed of the vehicle. The degree of environmental protection indicates the degree of environmental pollution and energy consumption by using this kind of vehicle.

By contrast, the features of car-share are that they do not need to buy their own cars, it is cheap and easy to use. The characteristic of ride-share is to share the cost of car fare with others, but it is not convenient to find the customers on the road. Self-driving cars is characterized by its need to purchase its own car and undertake a series of expenses, such as parking fees, road use fees. When we are traveling that needs to find parking spaces, and its convenience is very low. Flying cars is very expensive, but it is very fast, and it slows down the pressure of land traffic in the air which is very environmentally friendly. Hyperloop has a very high speed, but it can only carry 4-6 people at a time. The means of transportation need to travel to a specific location, and the convenience is not high.

For today's world, flying cars and Hyperloop are not widely used. Car-share, ride-share vehicles are still fuel vehicles, and electric cars is the most environmentally friendly and economical means of transportation. Because of the improvement of people's awareness of environmental protection, we will develop in ten years according to our development plan. In 20 years, with the development of science and technology, when car-share, ride-share vehicles also use electric vehicles, and the convenience of charging and exchanging of electric vehicle stations can be fully realized, the growth rate of electric cars will increase. 20 years later, Hyperloop and flying cars are becoming more and more popular, and their speed advantage will be the primary reason why people choose it. Flying cars, in particular, is an important progress in human science and technology. Its novelty and high speed will attract people's purchase. If it can be achieved, then flying cars will be a consideration for people buying a car, which is an important reason for the decline in sales of electric cars, which will affect the development plan.

7.Strength and Weakness

Strength

- We have made bold assumptions that we only consider the construction of fast charging stations. We believe that when the number of charging stations can meet all the electric vehicles in the US, the electric vehicle can get on the right track.
- We skillfully used the number of charging stations to solve the problem, first calculate the maximum demand of total stations, then according to the location model of city charging station number, determine the proportion of the city, we according to different ratio to determine the charging station in other areas
- The plan for building a station is variable and controllable

Weakness

- we do not have enough data to solve the model
- No consideration is given to the mixed charging mode.

Handout

In order to solve the problems of environmental pollution and climate change, the new energy vehicles especially electric vehicles are developed all over the world. The key to the full implementation of the electric vehicle is to be convenient. For electric cars, the most important thing is whether the charging is convenient, so we must determine the location and quantity of the charging station reasonably.

The choice of a country to develop electric vehicles instead of fuel vehicles must not be achieved overnight. It is necessary to make plans according to the state's own situation. If the terrain changes greatly, the charging station is hard to build. The government needs more time to transform the terrain. If the country's economic strength is not developed, it will directly extend the development cycle.

In the early stages of development about 10 years, we plan to build infrastructure to attract consumers to buy electric cars. Due to technical limitations, the price will be higher than that of conventional vehicles. The government should give some subsidies, and the initial charging station should consider only the construction in the city. This is because in the high level of economic development, traffic developed, city residents' environmental awareness is also higher than the rural and suburban areas. We can use advertising, news and other ways to publicize electric cars, popularize the awareness of electric cars, and increase the strength of the development of electric vehicles.

In the middle of development, it is planned for 10-20 years. Infrastructure construction has been basically completed, and the technology is developing slowly, so the electric car prices began to show the advantages. The government should reduce subsidies, and improve the construction of infrastructure. Then we began to layout in suburban and rural areas, and implement the ban part of the vehicle. The government intensify propaganda that improve the level of use of electric vehicles better and attract more people to buy electric cars.

In the late period of development, it was planned for 20-30 years. We complete a comprehensive ban on automobiles, fines the fuel vehicles, and to implement all motorized urban, suburban and rural areas. At this point, the government does not have to subsidize electric cars, but it needs to pay attention to problems such as maintenance, such as maintenance.

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