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2018
MCM/ICM
Summary Sheet

Embrace All-Electric Vehicles Era

Summary

All-electric vehicles era is coming. In order to identify the number and distribution of charging stations and propose advice, we developed three models: **Charing Network Model**, **Operation Model** and **Investment Model**.

Firstly, we set up a series of characteristics of all-electric vehicles era considering ***Tesla Company***, ***Government*** and ***Customer*** respectively. We concluded that Tesla is on the track allowing the switch to all-electric vehicles comparing the current performance with the characteristics of all-EVs era.

Secondly, a general **Charing Network Model** was established to determinate the number and distribution of charging stations in U.S and South Korea through **Queue Theory** and **Linear Programming** methods. We assumed that destination chargers are built around shopping centers, restaurants and hotels while supercharging stations are built along the road. In the result, we got the optimal number and distribution of charging stations.

Thirdly, we came up with two models to propose advice for the switch to all-EVs in South Korea. **Operation Model** was established by calculating the ***Accumulated Cash Flow*** of operating a charging station. In the result, we found that the urban chargers can profit until the eighth year since its installment while the rural chargers takes 36 years to do so. Therefore, the urban chargers should be installed first. **Investment Model** was established by calculating the time line of our growth plan. Finally, The extension of our models and a classification system were studied. We proved that our models also apply for other countries by comparing the time taken to evolve five million electric-vehicles from zero. What's more, technological impact was considered in our models.

The stability of our models was analyzed. We also discussed the strengths and weaknesses.

Keywords: Charging Network   Queue Theory   Time line

Contents

1 Introduction

1.1 *Background*

In recent years , electric-vehicles are more and more popular among people because their better user experience and more convenient charging network. However, switch to all-electric vehicles era also has a long way to go. The number and distribution of charging stations are critical to popularize the electric vehicles. In order to find out the optimal number and distribution of charging stations, we explored the previous studies related to this problem. Ramteen Sioshansi got the optimal locations of fast charging stations in Central-Ohio through a stochastic flow capturing location model (SFCLM) and he found that most stations are built around the urban core of the city[1]. Suqiang Zhao divided the total cost of charging stations into building cost, waiting cost and additional cost [2].

1.2 *Our work*

We have solved the following problems:

- Assessed the current and growth of Tesla charging network to identify if the Tesla can lead the switch to all-electric vehicles era in U.S.
- Established **Charging Network Model** that apply for U.S and South Korea to determinate the number and distribution of charging stations .
- Set up **Operation model** and **Investment model** to propose advice for the evolution to all-electric vehicles era.
- Estimated the time line of our growth plan by calculating the **Accumulated Cash Flow** of operating a charging station in urban and rural areas respectively.
- Extended our model to other countries and created a classification system instructing a nation to make policies to accelerate the switch to all-electric vehicles era.
- Took the technological impact on the use of electric vehicles.
- Provided a page of handout for leaders attending to the International Energy Summit.

2 Assumptions

- The destination chargers are around the shopping centers, restaurants and hotels according to [1].

- Supercharging stations are located at urban, suburban and rural roads.
- The average useful life of a charger is 10 years.

3 Switch to All-electric Vehicles Era

In recent years, electric vehicles industry has been developing rapidly. Some countries also formulate polices to accelerate the switch to all-electric vehicles era. In the industry, Tesla Motor has become a leader with technic and operational advantages. Tesla Model S and Tesla Model X have achieved great success. In the same time, Tesla Model 3 is also in high demand. In order to determinate if Tesla is on the track to allow the switch of all-electric vehicles(all-EVs) in the US, we chose three aspects to assess: ***Tesla Company***, ***Government*** and ***Customer***. Through **Linear Programming**, we also estimated the total number and distribution of charge stations in urban, suburban and rural areas if everyone switched to all-electric personal passenger vehicles in the US.

3.1 Assessment of Charging Network in U.S

First, we listed the characteristics of all-electric vehicles(all-EVs) era in *Electric-vehicles Company*, *Government* and *Customer* aspects respectively. Then, we explored the current performance in these three aspects. Finally, we determined that Tesla is on the track to allow the switch of all-electric vehicles in the US comparing the current performance with the characteristics of all-electric vehicles era.

Characteristics of all-EVs Era When the era of all-EVs has come, electric-vehicles will be popularized among all classed of people no matter they are rich or poor just like the current private cars. This will require the company, government and customer to have the following characteristics:

Aspects	Characteristics
Company	Enough output Reasonable price for ordinary people Reasonable distribution of chargers Enough 4S stores for product sale
Government	Provide subsidies Support policies Tax credit
Customer	Enough purchasing power Willingness to buy

Table 1: Characteristics of All-electric Vehicles Era

Current performance In this section, we explore the above aspects. The analysis of this aspect is consisted of a series of internal factors related to the performance of the company such as Strategy, Product, Charge Station, Operation and Research development. We consider external factors such as policy orientation and purchasing power in the analysis of company and customer respectively.

Tesla Company

- Strategy
  Tesla company is the first electric-vehicles company to go public in the US. In the early stage, Roadster is the main product priced at about $10,000 and mostly sold to rich people. In 2012, Tesla released Model S priced at about $50,000. In 2017, Elon Musk issued the Model 3 priced at about $35,000 which will be affordable for ordinary people in the US. From the price tendency of Tesla electric-vehicles, we can find out the strategy of Tesla is popularizing the Evs step by step.

- Product
  The two main current vehicles models are Model S and Model X. From the Figure 1 from [4], we can find the sales remain increasing by years.

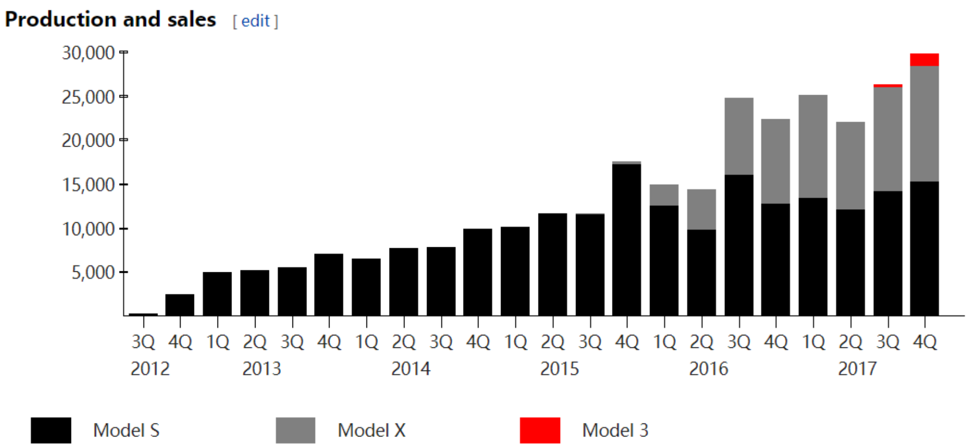

Figure 1: Tesla Sales

- Charge Station
  An important constraint factors of switch to all-Evs era is the number and location of charge stations. Currently, Tesla offers two ways for changing:**Destination Charge Station** and **Supercharger Station**. **Destination Charger** provides chargers at hotels, resorts, and restaurants around the country so people can top up their Model S′ batteries while grabbing a bite or spending the night [5]. **Supercharger Station** allow longer journeys for people through quick charging of the vehicle's battery packs [6]. Tesla also invest a lot to build Supercharger Station around United States.

Figure refNumber indicated the number and growth of Supercharger Stations over time in United States. We also explored the distribution and the overlap in the range of $150km$ of Supercharger Stations in United States as Figure 3 and Figure **??**shows.

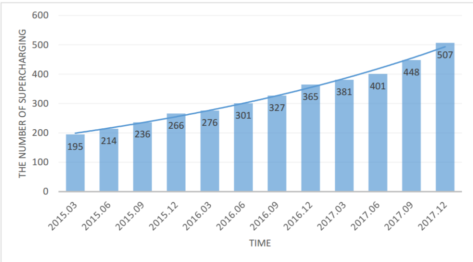

Figure 2: Number and Growth of Supercharger Stations[7]

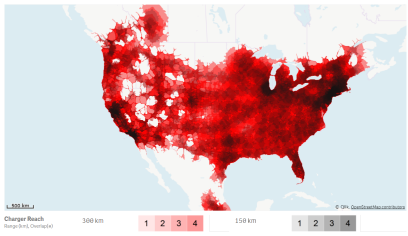

Figure 3: Network of Supercharger Stations[7]

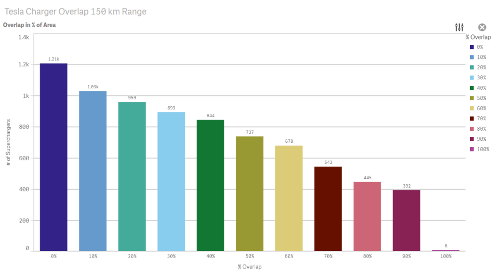

Figure 4: Overlap of Supercharger Stations[7]

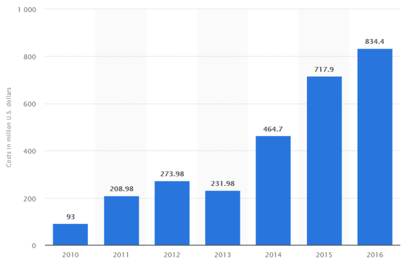

Figure 5: Research and Development of Tesla[8]

- Research development
  Tesla needs to keep researching to develop more powerful chargers because charging electric-vehicles will be more convenient than now when the all-Evs era comes. So, we find out the R&D expenditure from the 2017 financial report of Tesla. Figure 5 illustrates Tesla keeps increasing research and development expenditure.

Government Policy orientation In order to accelerate switch to all-electric vehicles, The federal government has formulated a series of policies to support the EVs such as tax credit, investments in R&D and competitive programs [9]. The American recovery and reinvestment Act also established tax credits(between \$2500 and \$7500 per vehicle)and subsidies(\$4000 per vehicle, maximum) for purchasing EVs.

Customer We use market share of Tesla to reflect the customer aspect because it can reflect the popularity among the customers in United States. According to news from Forbes, Tesla has dominated the EVs market in United States [10].

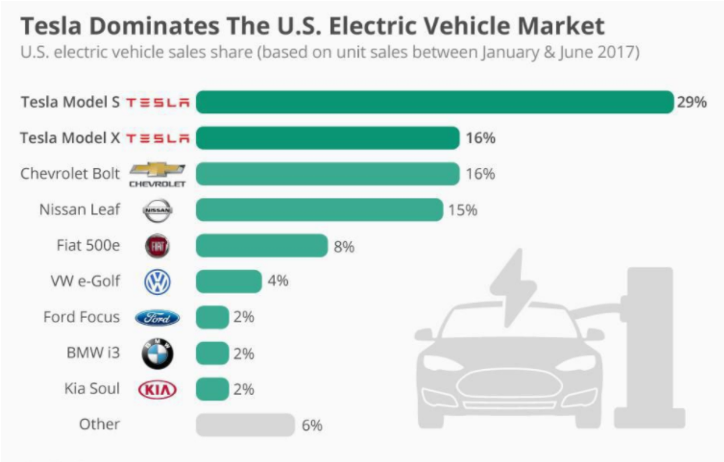

Figure 6: Tesla Market Share

Conclusion In Section 3.1, we set up some characteristics related to ***Tesla Company***, ***Government*** and ***Customer*** in all-electric vehicles era respectively. Then, we explored the corresponding current performance. From the perspective of ***Tesla Company***, We found that the strategy of Tesla is coincident with the switch to all-EVs era. The distribution of Supercharge Stations have covered most area of United States and the number of them has been increasing since 2015. Moreover, Tesla keep incremental research expenditure to develop more powerful cars and chargers. When it comes to ***Government***, the federal government formulate policies to support EVs. In the ***Customer*** aspect, Tesla dominates the EVs market in United States.

In general, we can determinate Tesla is on the track allow a complete switch to all-electric vehicles in United States.

3.2 Charging Network Model

In this part, we identified the number and distribution of charge stations when everyone has switched to all-electric vehicles. First, we defined a series of parameters related to urban, suburban and rural area. Subsequently, we found the data corresponding parameters. Finally, through **Queue Theory**, we got the number of chargers and their distribution between urban, suburban and rural areas.

3.2.1 Model in U.S

Parameters We defined parameters in Table 2.

Establish Model

- The Destination Chargers in three places
  We use **Queue Theory** to calculate the numbers of Destination Charger-

Aspects	Describe	Symbol	Unit
Urban area	The number of shopping center in U.S	N_1	1
	The number of restaurant in U.S	N_2	1
	The number of hotel in U.S	N_3	1
Suburban area	The road length in Urban area	L_1	km
	The road length in Suburban area	L_2	km
Rural area	The road length in Rural area	L_3	km
Traffic Flow (day)	Urban roads	P_1	1
	Suburban roads	P_2	1
	Rural roads	P_3	1
	Shopping center	F_1	1
	Restaurant	F_2	1
	Hotel	F_3	1

Table 2: Parameter Definition

Aspects	Describe	Symbol	Unit
The number of vehicles need charge per hour	Shopping center	λ_1	1
	Restaurant	λ_2	1
	Hotel	λ_3	1
	Urban road	λ_{r1}	1
	Suburban road	λ_{r2}	1
	Rural road	λ_{r3}	1
The number of vehicles charged per hour	Shopping center	μ_1	1
	Restaurant	μ_2	1
	Hotel	μ_3	1
	Urban road	μ_{r1}	1
	Suburban road	μ_{r2}	1
	Rural road	μ_{r3}	1

Table 3: Parameter Definition

s around the shopping centers, restaurants and hotels respectively. First, we assume that the probability distribution of vehicle arrive at these three places obeys **Poisson Distribution**. Each charger runs independently and its service time obeys negative exponential distribution. So we use **Queuing Model with Multi-server)(M/M/S)**, we defined S_1, S_2, S_3 to represent the optimal number of chargers the place should install which we need to identify. Second, we define the *total cost per day(C) of each charger* as the target function in Equation [2]through **Linear Programming**.

$$\min C = C_c + C_w \tag{1}$$

where

$$C_c = 500 \cdot \sum_{i=1}^{3} N_i \cdot S_i$$

$$C_w = 3.8116 \cdot \sum_{i=1}^{3} N_i \cdot W_{qi} \cdot \lambda_i \cdot T_i$$

$$\lambda_i = \frac{F_i \cdot \eta_i}{T_i}$$

$$i = 1, 2, 3$$

$$where \qquad \lambda_1 = 321 \quad \lambda_2 = 240 \quad \lambda_3 = 250$$

where C_c is the building cost per day through **Straight-line Depreciation Method** of each charger and C_w is the waiting cost caused by queuing. W_{qi} is the average waiting time of the three places. T_i η_i are defined in Table 4. we defined **Service Intensity(**ρ_{si} as following. Considering the system should formulate statistical equilibrium, ρ_{si} usually less than 1. Finally, we can get the number of chargers in the three places in Table 5 using **Linear Programming**.

$$s.t. \qquad \rho_s = \frac{\lambda_i}{S_i \cdot \mu_i} < 1 \quad i = 1, 2, 3 \tag{2}$$

$$\mu_1 = 0.5 \quad \mu_2 = 0.299 \quad \mu_3 = 0.5$$

- The Supercharger Stations on road
  We also use **Queue Theory** and **Linear Programming** to identify *the optimal density*α_i of Supercharger Stations in Figure 7 and *the optimal number of chargers in a Supercharge Station*β_i on road as shown in Figure. First, We

	Service Time ($T(hour)$)	Charge Ratio(η_i)
Shopping Center	14(8:00a.m-22:00p.m)	30%
Restaurant	12 (10:00a.m-22:00p.m)	30%
Hotel	10 (22:00p.m-8:00a.m)	80%

Table 4: The definition of Charge Ratio

classified road by urban, suburban and rural areas. Each type of road has different traffic flow. Second, we modified Equation 1 by adding *the additional cost(C_d)* driving to Supercharge Stations in Equation 3 by replacing ρ_{si} with **Service Intensity on road**ρ_{ri} in Equation

$$\min C = C_c + C_w + C_d \tag{3}$$

where

$$C_c = 250000 \cdot \sum_{i=1}^{3} \frac{\beta_i \cdot L_i}{\alpha_i}$$

$$C_w = 24 \times 91.5 \cdot \sum_{i=1} W_{si} \cdot \lambda_{ri} \cdot C_d$$

$$C_d = \sum_{i=1}^{3} \frac{\alpha_i}{4} \cdot 24 \cdot \lambda_{ri} \cdot k \cdot \frac{L_i}{\alpha_i}$$

$$\lambda_{ri} = \frac{P_i \cdot \eta_r \cdot \alpha_i}{24 \cdot Dis}$$

where

$$i = 1, 2, 3$$

$$s.t. \qquad \rho_{ri} = \frac{\lambda_{ri}}{S_i \cdot \mu_{ri}} < 1 \tag{4}$$

where W_{si} is the average duration of stay, $\frac{\alpha_i}{4}$ is the average distance form the nearest Supercharge Station,eta_r is defined as the *charge ratio on road* which is equal to 30% and k is money cost of per kilometer which is equal to $\$0.0284$. Dis is defined as $180km$. Finally, we can get the *the optimal density*α_i of Supercharger Stations and *the optimal number of chargers in a Supercharge Station(β_i)* on road which are shown in Table 6.

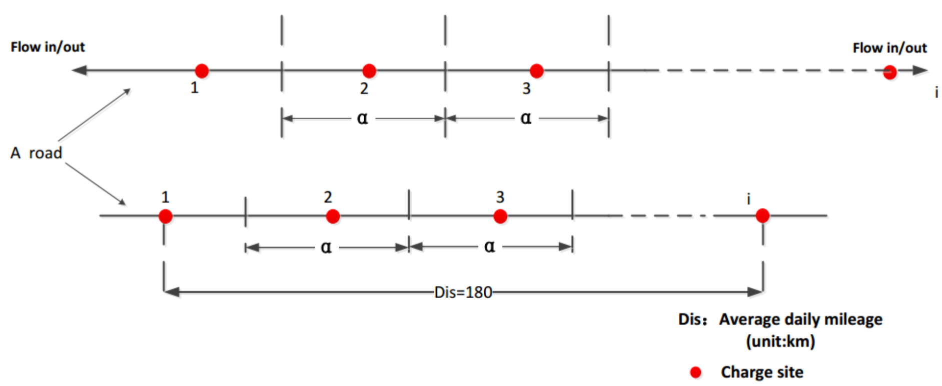

Figure 7: The Optimal Density of Supercharge Station

Place	Quantity	Chargers(one place)	Total Chargers
Shopping Center	10773	718	77381014
Restaurant	614460	588	361302480
Hotel	10941	884	9671844

Table 5: Result of placement circumstance

	L_i	P_i	α_i(1000km Range)	β_i	Total chargers
Urban road	3901225	22500	6.8	10	263596
Suburban road	4306735	15000	7.4	10	319017
Rural road	4712246	10000	8.2	10	386249
Total					968862

Table 6: Result of Road circumstance

3.2.2 Model in South Korea

Result Electric-vehicles are also more and more popular in South Korea. In this section, we determined the current number and distribution of the charging stations in South Korea. In order to promote the switch to all-electric vehicles era, we came up with a series of proposal considering the country's economic, population, infrastructure. What's more, we got the time line of our growth plan to evolve towards all-electric vehicles era gradually.

The Number and Distribution of the Charging Stations As we have established the model of charging network in United States, we can get the number and distribution of charging stations through putting the data of South Korea into the model.

- Result The result of South Korea are showed in Table 7, 8.
- Key Factors
  The number and distribution of charging stations depends on variable fac-

Place	Quantity	Chargers(one place)	Total Chargers
Shopping Center	1200	273	327600
Restaurant	4500	606	2727000
Hotel	4466	693	3094938

Table 7: Result of placement circumstance in South Korea

	L_i	P_i	α_i(1000km Range)	β_i	Total chargers
Urban road	2237	25171	8.7	10	195
Suburban road	1485	13162	22.7	2	68
Rural road	787	10000	17.2	3	41
Total					304

Table 8: Result of Road circumstance in South Korea

tors. In order to identify the charging network more precisely, we need to find the key factors which are dominated our model. Here are the key factors we have found out.

1.**Traffic Flow** Our model is established based on the **Queuing Model with Multi-server)(M/M/S)**. Using this method, one of the most important parameters is the number of vehicles need charge per hour(λ_i) while λ_i is determined by the **Traffic Flow**. So, **Traffic Flow** is the key factor in our model.

2.**Charging Time** Another important parameter is the number of vehicles charged per hour(μ_{r3}). μ_{r3} is determined by the **Charging Time**. Besides, shorter charging time, better user experience.

3.3 Proposal for Evolving the Charging Network

Aim at proposing the evolution to all-electric vehicles, we developed two models which are **Operation Model** and **Invest Model** from the perspective of operating and investing.respectively. **Operation Model** proposed the total building cost of Supercharger is so large that the government should give support. **Invest Model** explained the time line of our proposed growth plan. Both the models proposed chargers should be built before hoping people buy cars and city-based chargers should be installed first. We also considered the key factors of the two models respectively.

3.3.1 Operation Model

- Assumptions

1. The specification of chargers is illustrated in Table 9. The charging time of each charger is 45minutes

2. We assume that the service time of a charger is from 9:00a.m to 21:00 p.m and a charger can work 200days one year. During this time, the charger can charge 10 vehicles.

3. Each charger charges a vehicle $20kWh$. We considered a vehicles need to be charged when its battery has 40% left and can be charged to full-battery. Because some chargers will be in idle while others in work in a charge station, we assume all chargers charge a vehicle $20kWh$ in a charge station.

4. The charge price is $\$0.265/kWh$. The power supply company, electric-vehicles and charge station can earn $\$0.139/kWh$, $\$0.107/kWh$ and $\$0.02/kWh$

	Invest cost	Installment cost	Transform cost	Total
Cost($)	7940	10163	5717	2380

Table 9: Cost of chargers

from the charge price respectively. What's more, the electric-vehicles will tax 10% of its revenue.

5. The distribution of chargers between urban and rural areas is according to the population proportion. The maintenance cost of a charger in rural areas is $\$159$ a year. Considering the frequency of use in urban areas, the maintenance cost of a charger is incremental until arriving at a specific level.

- Parameters
we defined seven parameters in Table 10 to calculate the annual net income of the electric-vehicles.

- Establish Model
We defined Equation 5 6 to calculate Y_1, Y_2 respectively.

$$Y_1 = R \cdot Q \cdot E \cdot A \cdot X - Z \tag{5}$$

$$Y_2 = R \cdot Q \cdot E \cdot A \cdot X \cdot K - Z \tag{6}$$

- Result
We got the Y_1, Y_2 using the above model. Through the changing accumulated cash flow over time in Table 8 9, the urban chargers profit until the

Symbol	Unit	Description
R	$\$$	The revenue of the EVs company per kWh
Q	$\$$	The number of vehicles a charger can serve per day
Z	$\$$	The building cost of a charger
E	kWh	The energy of a vehicle charged one time
A	day	The working time of a charger per year
X	$\$$	The tax income of the government per year
K	1	The ratio of rural population to urban population
Y_1	$\$$	The revenue of the EVs company from urban chargers per year
Y_2	$\$$	The revenue of the EVs company from rural chargers per year

Table 10: Parameters

eighth year since its installment while the rural chargers need 36years to profit. **From this point, we propose urban chargers should be installed first.What's more, the government should provide support because of the slow capital return**.

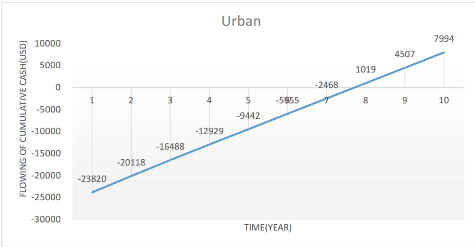

Figure 8: Accumulated Cash Flow of urban chargers

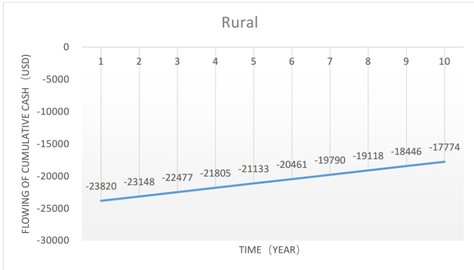

Figure 9: Accumulated Cash Flow of urban chargers

- Key factors
  This model calculated the accumulated cash flow of operating chargers in urban and rural areas respectively. The cash flow is determined by the number of electric vehicles of corresponding area while the number of electric vehicles is determined by the level of urbanization of a country. So, the level of urbanization is the key factors.

3.3.2 Invest Model

- Proposal and Assumptions

  1.We propose that the government of South Korea would invest total 10000 chargers in urban and rural areas simultaneously every year and the profit produced from chargers would be invested to install new chargers.

  2.We assume that the distribution of chargers between urban and rural areas is according to the population proportion.

  2.We don't take the damage of chargers into consideration during the its working time.

  3.We propose the fiscal budget of South Korea would keep balance during the investment.

  4.In order to promise people can charge their vehicles conveniently, we assume that the number of chargers is equal to electric-vehicles.

- Establish Model
  We defined parameters in Tale 11. We can get the q_{i+1}, p_{i+1} and m_{i+1} through the Equation 7, 8, 9.

$$q_{i+1} = q_i + \frac{r_i}{Z} \qquad i = 1, 2, 3, \cdots \tag{7}$$

Symbol	Unit	Description
q_i	1	The number of urban chargers in the ith year
p_i	\$	The number of rural chargers in the ith year
r_i	\$	The revenue of urban chargers in the ith year
v_i	kWh	The revenue of rural chargers in the ith year
m_i	1	The total number of chargers of urban and rural areas

Table 11: Parameters

where

$$r_i = Y_1 \cdot p_i$$

$$p_{i+1} = p_i + \frac{v_i}{Z} \qquad i = 1, 2, 3, \cdots \tag{8}$$

where

$$v_i = Y_2 \cdot q_i$$

$$m_i = p_i + q_i \qquad i = 1, 2, 3, \cdots \tag{9}$$

- Result
  According to the population and the per capita car retention rate of South Korea from [13], the total number of gasoline and dispel vehicles is about ten millions currently. Through the model, we get the magnitudes of q_{i+1}, p_{i+1} and m_{i+1} over time in Figure 10. From Figure 10, **the number of urban chargers increases exponentially while rural chargers increases very slowly**.

- Timeline
  As we have known the current number of gasoline and dispel vehicles, we could estimate the time line of our growth plan in Table.

- Key factors
  This model solved the change of the number of chargers over time. As Figure 10 shows, the number of urban chargers increases exponentially. In the model of exponential growth , the quantity largely depends on the base number. Therefore, the number of chargers a country invested in the first year is key factors.

Scale of electric-vehicles	Time taken
0%	0 year
10%	21 years
30%	28 years
50%	32 years
100%	37 years

Table 12: Time line

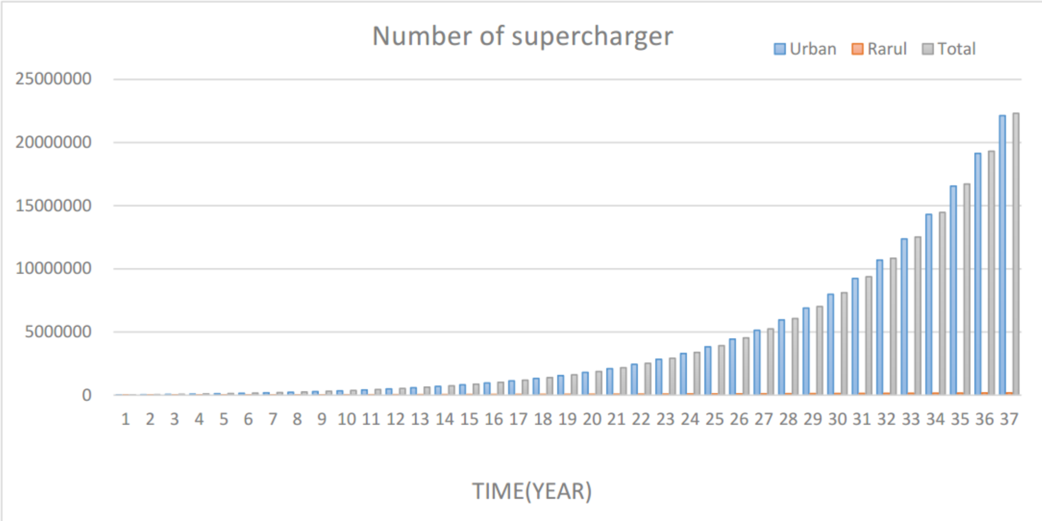

Figure 10: q_{i+1}, p_{i+1} and m_{i+1}

4 Model Extension and Classification System

In the previous sections, we have discussed the charging networks in United S-tates and South Korea respectively. Now, we extend our model to more countries varying geographies ,population density distributions and wealth distributions. In order to find out if our model still apply for these countries, we changed the input with the data corresponding to these countries. Furthermore, we set up a classification system instructing others countries to successfully migrate away from the gasoline and dispel vehicles.

4.1 Model Extension

We are required to extend out model to Australia, China, Indonesia, Saudi Arabia and Singapore. Australia and Singapore are developed countries which means the level of urbanization is higher compared to the other countries. High level of urbanization indicates the country need to install urban chargers first while lower level of urbanization indicates the country need to install urban and rural chargers simultaneously. We proved our model also apply for these countries by comparing the time taken to evolve five million electric-vehicles from zero as Table 13 shows.

4.2 Classification System

Based on the above analysis, we can formulate a classification system to instruct other countries to make policies. The system takes **The level of urbanization** and **GDP** into consideration.

Countries	Is developed country	Time taken
Australia	Yes	29 years
China	No	18 years
Indonesia	No	38 years
Saudi Arabia	No	40 years
Singapore	Yes	42 years
South Korea	Yes	30 years

Table 13: Extension Result

Classification System

The level of urbanization	Higher level	$\longrightarrow$	Install urban chargers first
	Lower level	$\longrightarrow$	Install urban and rural chargers simultaneously
GDP	Higher level	$\longrightarrow$	Radical gasoline vehicles ban policy
	Lower level	$\longrightarrow$	Conservative gasoline car ban policy

5 Technological Impact

In recent years, technologies have developed rapidly and changed our world greatly. Electric-vehicles popularity can attribute to the development of charging technology. In the same time, the evolution to all-electric vehicles era is also effected by other technologies such as car-share, self-driving cars, rapid battery-swap stations, flying cars and Hyperloop. In this section, we discussed the impact of these technologies on the switch to all-EVs era.

- Car-share
  Car-share can significantly reduce the cost of daily traveling of people. The demand of personal electric-vehicles may decrease because some people prefer traveling through car-share than possessing an electric vehicles.

- Self-driving cars
  If the self-driving cars are electric vehicles, the use of EVs will increase significantly. Self-driving cars are more convenient and safer compared to the ordinary electric vehicles.

- Rapid battery-swap stations
  Rapid battery-swap stations provide fully charged batteries for electric-vehicles. The waiting time at rapid battery-swap stations would decrease significantly compared to charge stations. The accumulated cash flow of building a battery-swap station is showed in Figure 11. From the figure, we can find the current building cost of battery-swap stations is high and this will result swapping a battery is expensive. However, if the technology of swapping-battery makes a breakthrough which diminishes the swapping

price greatly to the extent of the charging station, the use of electric-vehicles will be increased significantly because of the less time cost when charing a car.

- Flying cars
  Flying cars make people full of imagination. They have unique advantages. For example, flying cars are not limited to specific routes and more faster than ordinary electric vehicles. If the fling cars are popularized, they will replace the electric-vehicles and become a main choice for ordinary people.

- Hyperloop
  A hyperloop comprises a sealed tube or system of tubes through which a pod may travel free of air resistance or friction conveying people or objects at high speed while being very efficient [15]. This concept was first publicly by Elon Musk [15]. A hyperloop would be a piece of better advice for long-distance journey while electric-vehicles are proper for short-distance journey. So, the hyperloop can decrease the use of electric vehicles from the perspective of long-distance. When it comes to short-distance, the hyperloop can not impact the use of electric vehicles.

6 Stability Analysis

We did stability analysis on our models to identify how much the output would change if the input has changed 10%. The result illustrated the stability of our model is good.

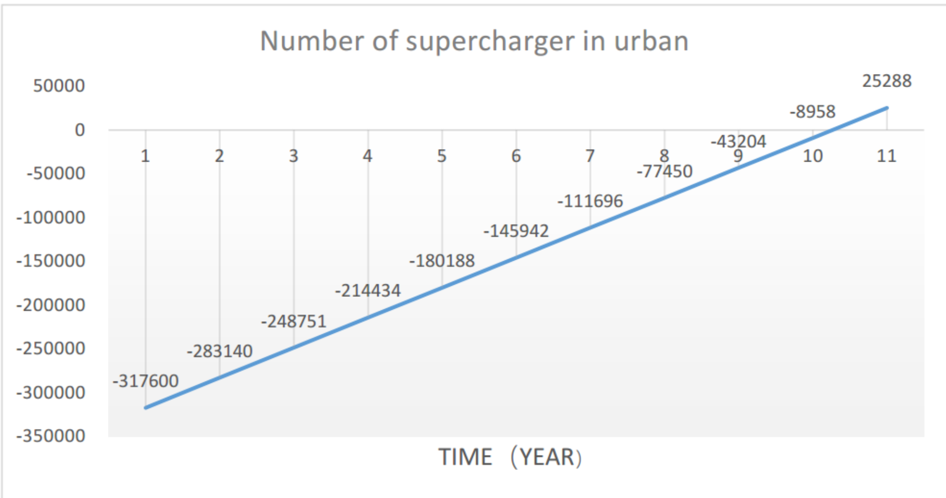

Figure 11: Accumulated cash flow of a battery-swap station[14]

6.1 Charge Network Model

The output has changed 3% as shown in Table 14.

6.2 Operation Model

When the input has changed 10% of operation model, the rural chargers realize profiting 15 years in advance .

6.3 Investment Model

When the input has changed 10% of investment model, the time line growth plan advances one year.

	Quantity	Traffic Flow(after change)	Total Chargers(after change)	Output Change
Shopping Center	1200	4841.2	297600	9%
Restaurant	4500	4149.6	2880000	6%
Hotel	4466	2111.2	2800182	10%
Total			5977782	3%

Table 14: The Stability of Charge Network Model

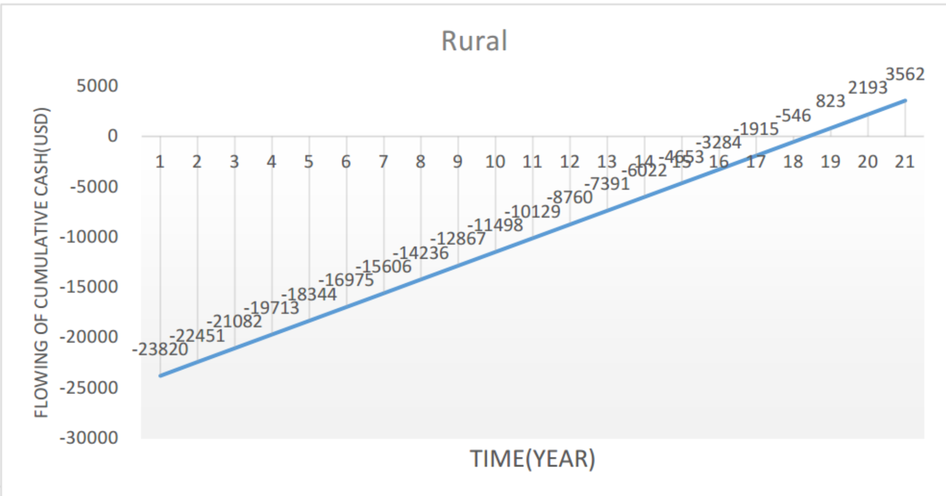

Figure 12: Stability of Operation Model

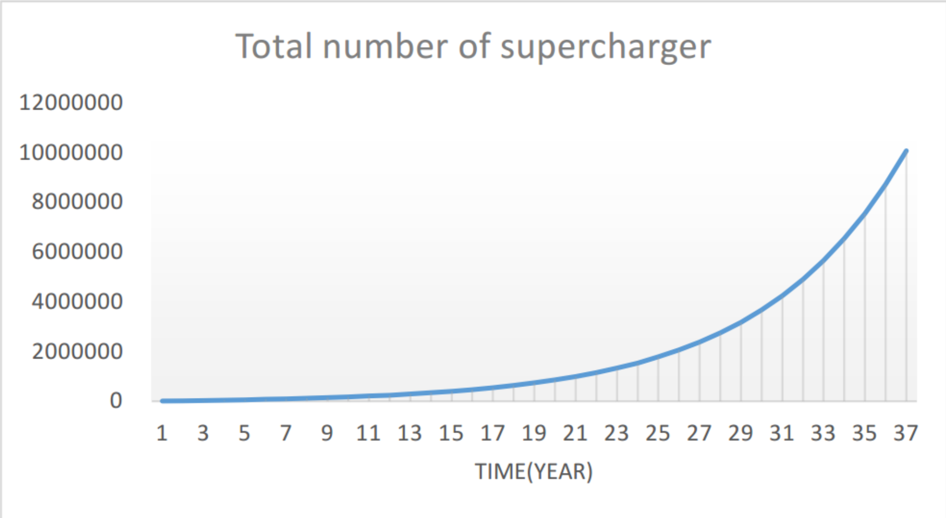

Figure 13: Stability of Operation Model

7 Strengths and Weakness

7.1 *Strengths*

- We established **a general model** that can apply for many counties to identify the number and distribution of charge stations just change the input data.
- We proposed our advice for country to operate and invest charge stations with **Operation Model** and **Investment Model** by calculating the **Accumulated Cash Flow** of charge stations.
- The stability of our model is good.

7.2 *Weakness*

- We don't take commercial and public vehicles such as heavy trucks and busses into consideration.

8 All-Electric Vehicles Era is Coming

Welcome to Internal Energy Summit! We provide a series of policies to embrace the **All-Electric Vehicles Era**.

- Make policies based on the domestic economic situation

  1. Countries with high level of urbanization should install urban chargers first and enact a radical gas vehicle-ban while countries with low level should install chargers in the urban and rural areas simultaneously and enact a conservative gas vehicle-ban.

  2. Adopt a series of policies to support the development of electric vehicle industries. For example, subsidy to electric vehicle buyers. Reduce tax for electric vehicles companies.

  3. Propaganda the benefits of electric-vehicles to motivate the demand for electric vehicles.

- Distribute charging stations optimally

  1. Make the optimal distribution of charging stations between urban, suburban and rural areas taking the traffic flow information , the building, maintenance and land cost of charging stations into consideration.

  2. Build charging stations around shopping centers , hotels and restaurants because people frequently go to these places.

  3. Identify the optimal number of chargers in a charging station according to the traffic flow at the corresponding places.

- Optimize the performance of electric-vehicles and chargers

  1. Improve capacity of batteries and make the vehicles safer.

  2. Shorten the charging time and decrease the installment cost of chargers.

  3. Produce various models of electric vehicles so that all kinds of people with different income and interest can purchase their satisfied vehicles.

- Develop high technologies

  1. Develop the battery-swap technology to decrease the waiting time at charging station.

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