For office use only	Team Control Number	For office use only
T1 ________________	**93534**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**D**	F4 ________________

2018
MCM/ICM
Summary Sheet

Driving on Electric Vehicles

Summary

As economical and environmental cost of the gasoline vehicles increases, many countries have started migrating from Gas-car to E-car. Our goal is to tell a country how to make the transition from gas vehicles to electric vehicles smoothly and efficiently. Rome was not built in a day. We have to consider many factors to proceed a successful transition.

Our analysis and modeling focus on two objects: E-Car and the country. First, we focus on E-car itself. After getting the distance Tesla could run with specific charging time, we build a simulation(micro) model. It forms an optimal distribution of supercharger stations and destination charger stations in a fixed length of road. Any country could calculate its ideal number and distribution of charging stations based on our simulation model.

Then, we build another two models based on characteristics of a country. Macro model shows the relations between the distribution of charging stations and many key factors, including high-way distribution, population distribution, economical development, vehicle volume and geographies. Via combining the micro and macro factors, we build an ultimate model which results in a specific transition plan and growth plan timeline. Since the lack of data, our model seems not that precise, but it's still very useful.

Moreover, we create a classification system to guide different countries determining the suitable growth model. We select America, Ireland and China as examples to explain our classification system.

Contents

1 Overview

1.1 Background

Major vehicles running on the road today are gasoline cars, and the most troublesome problem for gas-car drivers is the increasing price of gasoline. Because of the inelasticity of the demand for gasoline, drivers have no choice, but to consume the gasoline. As for the pedestrians, exhausted gas produced by the gasoline vehicles when these cars passed by is also annoying.

In recent years, the amount of the electric vehicles is growing for both environmental and economical reasons. The world sees the potential of this reliable substitution for highly-polluted gasoline vehicles, and many countries are promoting it in different ways, but the complements of these vehicles, such as chargers and batteries, seem not to be able to satisfy by this time.

1.2 Restatement of the problem

We need to analyze the change of proportion of electric vehicles, Tesla as our focus, in the urban and rural area. We also need to determine the future development of the implements, like charging stations, then connect to the economical and environmental factors in different countries and areas.

This problem can be separated into 4 parts:

- Analyze the growth pattern of Tesla in urban and rural areas, and connect it to different local factors.
- Build a simulation model to simulate the Tesla's energy use and distributions of charging stations.
- Build an evaluation model to rate the performance of each design related to its cost and efficiency.
- Connect our models to the real-life cases and take specific regions as examples.

1.3 Overview of our work

To begin with our approach, we study the development of Tesla and analyze the distribution of Tesla charging stations existing in US, China and Ireland nowadays. Then we predict Tesla development tendency. Our analysis can be briefly summarized into several parts:

- Analyze worldwide Tesla sales

Then, it comes to analysis and modeling part. We start with simulation model. Getting the distance a car can run after being charged for specific time, we try to minimize the input index which is defined by charger's price and efficiency.

- find the ideally optimal number of superchargers stations and destination chargers stations in a fixed distance, then combine and apply on different countries.

Then we build macro model. We analyze the relationship between the number of chargers and the following key factors separately:

- High-way Distribution
- Population Distribution
- Economic Development
- Vehicle Volume

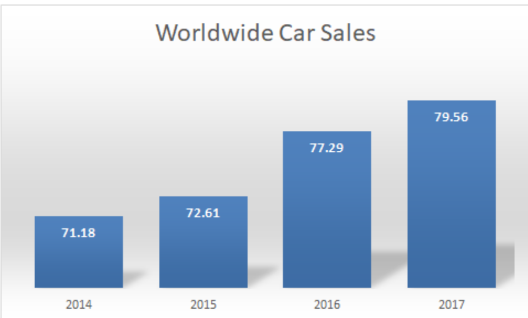
Then, we combine the micro model (the ideal one)and macro model to get an optimized model. And we try to apply this model to different countries and areas, especially on America, China and Ireland. We create proposals to prompt the chargers and electric vehicles in different countries.

Finally, we take the developing factor into the consideration, and try to fit the model into different countries and areas by changing the value of coefficient.

To sum up, our model is a sufficient and feasible model that can accommodate to different situations.

2 Analysis of the Problem

To analyze the growth rate of Tesla sales all over the world, we gather the data of total car sales and Tesla sales worldwide from 2014 to 2017. From the figures, we can see that as the rate of increasing of sales of total cars decreases, sales of Tesla still increase continuously and steadily.



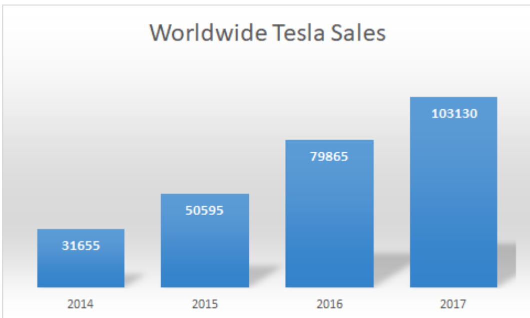


Figure 1: Global Vehicle and Tesla Sales

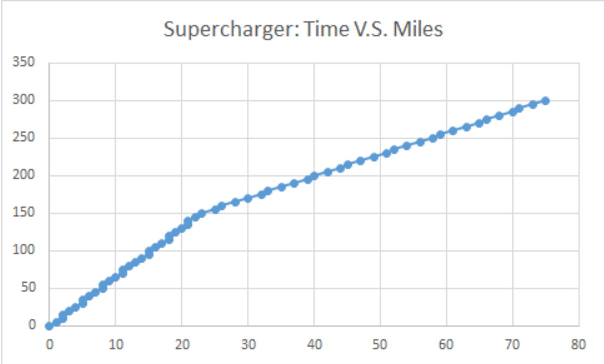


Figure 2: charging time related to the distance(in miles) one car run

3 Simulation Model

3.1 Straight road model for supercharger

By plotting the relation between number of miles that a car can run and the charging time it needs in the Figure 2, we find an inverse exponential relation between them, which is

$$S = 367 \times (1 - e^{-0.021t}) - 0.9523$$

.

Our simulation model will depend on this relationship and we will take some factors into consideration later. Suppose a person is willing to drive from New York to Virginia (the distance is 300 miles in total). In simulation model, we simplify the road between the two cities as a straight line. So we can calculate total time for charging when there are different number of charging stations in the distance of 300 miles:

total charging time and number of charging stations in 300 miles		
number of charging stations	average time/min	least time/min
1	81.666	81.666
2	55.583	50.464
3	50.141	45.962
4	47.934	44.167
5	61.460	43.250

And from these data, we can plot another graph: (the red line represents the relation between average time and the number of charging stations while the blue one represents the least time and the number of charging stations)

From the Figure 3, we can get that the least time declines with increasing of number of charging stations, while the rate of decreasing is decreases. The least time is also declining with increasing of number of charging stations, and the rate of decreasing is also decreases. We could see that average time has a very sharp increase when we increase the number of charging stations from 4 to 5, which implies that the advantage

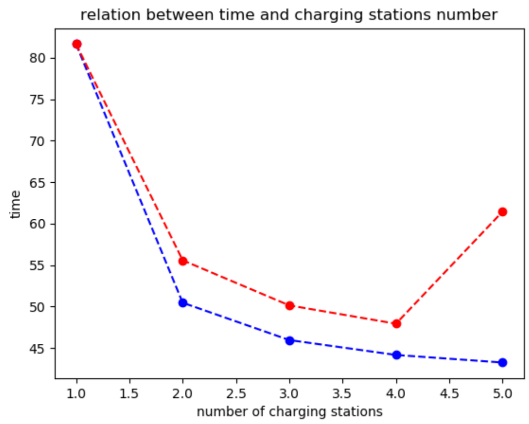


Figure 3: The charger station number vs time

of more charging stations exhibits decreasing returns-to-scale. At this point, we take the economic factors into consideration.

We define the input index for one supercharger for government as

$$GC = P \times e^T$$

in which P: the building price of a supercharger divides by 10000, and T: the average time we spend on charging in the fixed distance.

Based on our research, one Tesla supercharger will cost about \$150000 to build. We calculate the input index using formula above and plot the graph. From Figure 4, we can see that the input index for $n = 4$ is 33.35, which is the lowest point in the graph. This means building 4 charging stations in a distance of 300 miles is the optimal plan. Figure 5 is our simulation model of 4 charging stations in a distance of 300 miles.

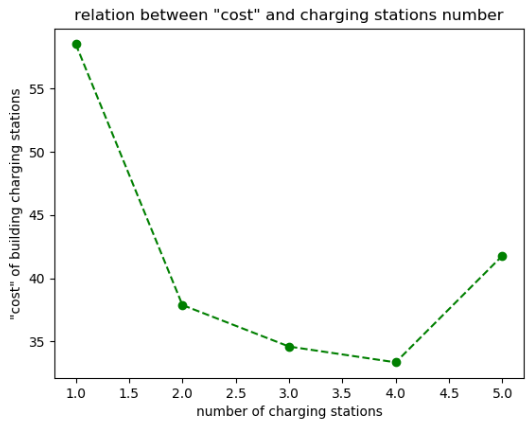


Figure 4: input index and number of charging stations

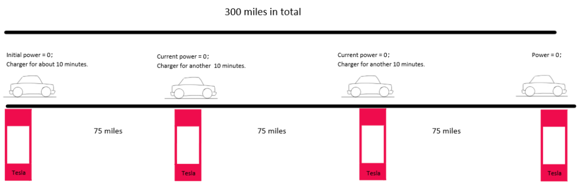


Figure 5: Four-charger condition

3.2 Straight road model for destination charger

Now, we consider the other type of charger – overnight destination charger.

Similarly, suppose the travel from New York City to Virginia is a 300 miles straight line, and the only existing type of charging station is destination charger.

In research, we find that the average price for a destination charger is around \$600, and the total time required for a destination charger to fill up a car is 10 hours. The formula represents the input index of government

$$GC = P \times e^T$$

will also be used here.

Assuming the total distance is 300 miles, we can get the number of overnight charger required is 1. Thus, the input index $GC = (600/10000) \times e^{10} = 1.32 \times 10^3$.

3.3 Combination of destination charger and supercharger

Since individuals could have their own travelling plans, we cannot only build one kind of charger. Someone may prefer taking a break each time after driving for several miles, while someone prefer driving for hundred miles and charge their cars overnight. Therefore, we have to build both supercharger and destination charger systems.

From analysis above, the optimal plan is to build 4 supercharger stations every 300 miles which is 1 supercharger per 75 miles, and 1 destination charger station every 300 miles.

The input index for 4 supercharger stations and 1 destination charger station is $GC = 4 \times 33.35 + (1.32 \times 10^3) = 1453.4$, and the actual cost for building stations is $4 \times 150000 + 600 = 600600$ dollars.

If we apply this simulation model on all the roads and highways in America, China and Ireland, we will get their ideal numbers of charging stations :

- America

  America has road length of $6,722,347$ km (which is 4177072 mi) and motorway length of $77,017$ km (which is 47856 mi). total length = 4177072 + 47856 = 4224928 mi. It needs $4224928 \div 75 \approx 56333$ superchargers stations, and needs $4224928 \div 300 \approx 14084$ number of destination chargers stations.

- China

China has road length of $4,696,300$ km (which is 2918145 mi) and motorway length of $125,373$ km (which is 77903 mi). total length= $2918145 + 77903 = 2996048mi$. It needs $2996048 \div 75 \approx 39948$ superchargers stations, and needs $2996048 \div 300 \approx 9987$ Destination Chargers stations.

- Ireland

  Ireland has road length of $96,155$ km (which is 59747 mi) and motorway length of 1017 km (which is 631 mi). total length= $59747 + 631 = 60378mi$. It needs $60378 \div 75 \approx 806$ superchargers stations, and needs $60378 \div 300 \approx 202$ Destination Chargers stations.

The calculation above shows the ideal number of charging stations in the three countries. In a fantasy world, we may replace all the gas cars to electric cars, and let every gas station replaced with a charging station. However, in reality, there are limited resources, and it will take time both for consumers to make the car switch and for government to replace gas stations gradually.

4 Macro Model

As nations plan the transition from Gas-cars to E-cars, they need to consider the final network of charging stations.

Take the distribution of charging stations in America as an example.

From Figure 6, we could feel that the density of charging stations distribution is higher in coastal areas. According to basic geography common sense, coastal areas are always richer than inland. So, we guess that the number of charging stations in urban areas are more than that in rural areas.

We begin the analysis based on the situation of U.S., and we list several factors of states which may have relations with distribution of charger:

- Highway Distribution
- Population Distribution
- Status of Economic Development

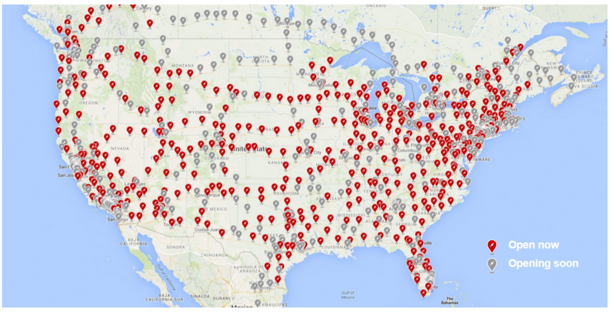


Figure 6: Tesla Chargers in U.S.

- Vehicle Volume

To decide whether these factors are related to distribution of Superchargers and how the relationships are, we collect and analyze following data to build relationship :

- Distribution of length of highway in each state
- Population of each state
- number of registered primary vehicles of each state
- GDP of each state

Symbol	Definition
SC	Number of supercharger stations of state
L	Length of Highway of state
L[U]	Length of highway in urban area of state
P	Population of state
P[U]	Population in urban area of state
V	Vehicle Volume of state
GDP	GDP of state

4.1 Length of Highway

We have built the simulation model for the relationship between distance driven and distribution of supercharger station. Thus, we first analyze the current relationship between length of highway and supercharger stations' volume.

In Figure 7-L, x-axis represents length of highway of each state in miles; y-axis represents number of supercharger stations. The blue points in the graph show the actual relation between length of highway and number of stations.

And we have separate urban regions and rural regions by building the relationship between state's highway length and number of supercharger stations in these two regions.

Through Figure 7-R, we may not find any direct relationship between length of highway and number of stations in rural area.

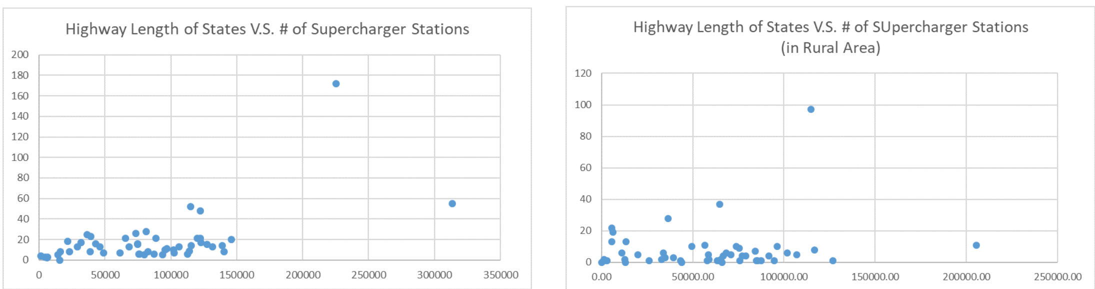


Figure 7: The number of Supercharger Stations related to length of Highway of each state and the relation in rural area

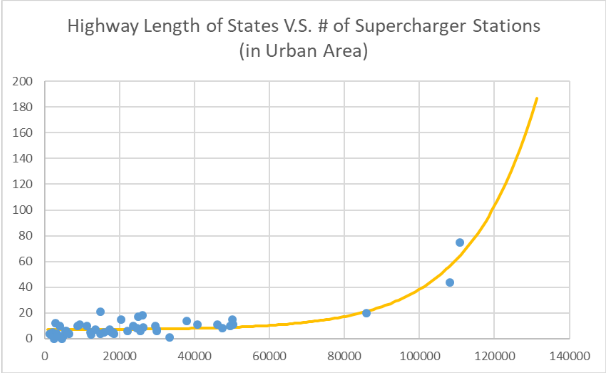


Figure 8: The number of Supercharger Stations related to length of Highway of each state in urban area

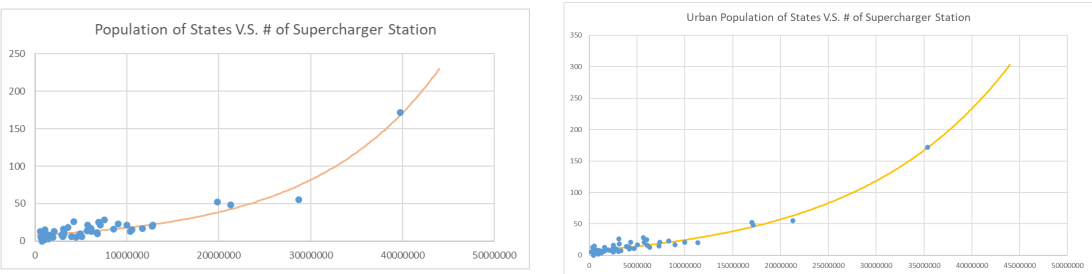


Figure 9: The number of Supercharger Stations related to length of Highway of each state, and of urban area of each

According to Figure 8, we find, in urban area, there is an approximate exponential relationship between highway length and supercharger stations' volume in each state, which is

$$SC = 0.119 \times e^{5.578\times10^{-5}*L} + 6.921$$

This relationship makes us be able to consider the whole model by considering the factor of length of highway, especially for the relationship in urban area.

4.2 Population distribution

Basically, the arrangement of superchargers should fit the demand of people in regions when the progress of switching to EV is finished. Thus, we collect the data from World Population Review for population of each state, and build the following chart for finding some relationships for current situation.

In Figure 9-L, x-axis represents population of each states in person; y-axis represents number of supercharger stations. The blue points in the graph show the actual relation between population and number of stations. According Figure 9-L, we find that there is an exponential relationship between population and number of Supercharger station, which is

$$SC = 9.255 \times e^{7.313\times10^{-8}\times P} - 1.349$$

And then we analyze the relationship between the number of supercharger stations and population in urban area for each state.

According to Figure 9-R, we found there is an exponential relationship between population and number of Supercharger station, which is

$$SC = 20.04 \times e^{6.272 \times 10^{-8} \times P[U]} - 13.09$$

4.3 Vehicle volume

Vehicle volume is also one factor that may have effects on arrangement of supercharger stations, because the direct effect of the progress is on the car and its using. So we use data from U.S. Department of Transportation Federal Highway Administration for number of registered primary vehicles of each state, and build the following chart.

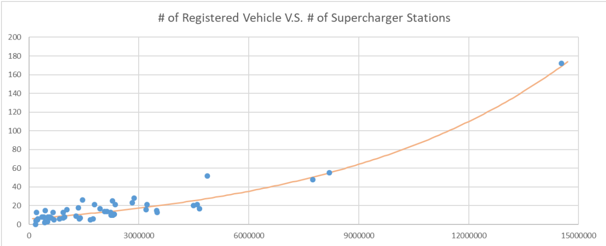


Figure 10: Number of Supercharger Stations related to registered vehicles volume of each state

In Figure 10, x-axis represents volume of registered vehicle of each states in unit; y-axis represents number of supercharger stations. The blue points in the graph show the actual relation between vehicle volume and number of stations, and we found there has the exponential relationship between vehicle volume and number of Supercharger station, which is

$$SC = 19.47 \times e^{1.549 \times 10^{-7} \times V} - 13.07$$

.

4.4 Economic development

The situation of economic development shows how much ability of a place may develop more attached devices for cars, such as supercharger stations. Thus,this is also a factor of arrangement of stations. We use the data from usgovernmentspending.com for GDP of each state, and build the following chart.

In Figure 11, x-axis represents GDP of each states in billion; y-axis represents number of supercharger stations. The blue points in the graph show the actual relation between vehicle volume and number of stations,and we can found there has an exponential relationship between GDP and number of Supercharger station, which is

$$SC = 20.23 \times e^{0.0007753 \times GDP} - 13.18$$

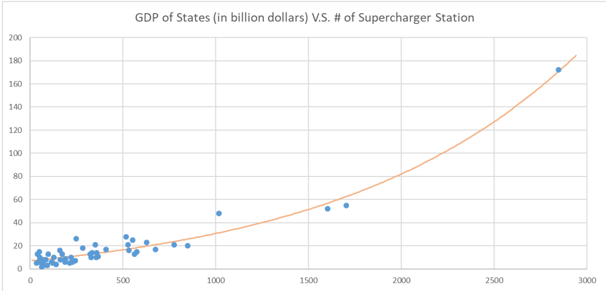


Figure 11: The number of Supercharger Stations related to GDP of each state

4.5 combined index

Based on the analysis for factor related to distribution of Supercharger, we build the combined index for these four factors to find the relationship between the comprehensive situation of states and number of supercharger stations:

$$Index = Max(GDP\%, P\%, V\%) - GDP\% \times 0.005 - V\% \times 0.0055 + P\% \times 0.0115 + L[U]\% \times 0.05$$

And the final relationship between current supercharger stations' volume and combined index is:

$$SC = 14.31 \times e^{0.1711 \times Index} - 7.265$$

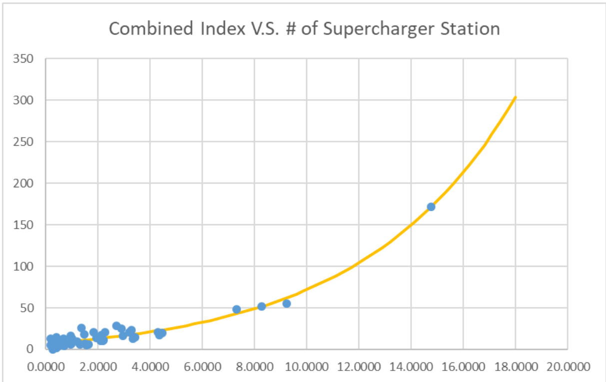


Figure 12: The number of Supercharger Stations related to Combined Index

5 Optimized the Model

5.1 Overview

From our macro model, we can find that the population distribution, economic development, vehicle volume, and the high-way using are all playing important roles on the number and distribution of charging stations. After find the optimize model, we should quantify the economic and practical(vehicle volume and high-way) factors. So, we introduce two coefficients, E, stands for economic factor, basically, we use the GDP(in

10-thousand dollar) times n in each area here, and C, stands for the convenient factor for the driver to access the charger, and we uses the distance between two charging location.

5.2 Differential Model

- Terms and Definitions

Symbol	Definition
D	Number of Destination Charger
S	Number of Super Charger total
E	Economic Factor
C	Convenience Factor
F	Constant coefficient for convenience calculation
n	Constant coefficient for economic

- Establishment From beginning of section 3, we saw a exponential relationship between economic factor and the number of vehicle, so we formulate two functions$D(E, C)$ and $S(E, C)$ to find the total number of charger station needed in a certain area

$$S(E, C) = 2e^{E \times n} sin\left(\frac{C}{F}\right)$$

  and

$$D(E, C) = 2e^{E \times n} cos\left(\frac{C}{F}\right)$$

6 Model Application

Now we apply two functions above to different countries, considering countries with very different population density distributions, wealth distributions and geographies.

But how do we prompt it? The evaluation model of the country comes out. During previous study, we have found that economic and population is strongly related to the ability of a country to invest the electrical vehicles. Now, we introduce two other factors, which is the existing proportion of the electric vehicles to the total vehicles, and the factor of government support. We simplify the government factor to be either 1 or 0, stands for support or not. As for other factors, we use the rank of it in the world and utilize the top percentage of it into our calculation. According to the summation form of comprehensive evaluation model

$$P = \sum_{n=1}^{4} (a_n \times p_n)$$

with

Symbol	Definition
a_1	Vehicle volume factor
a_2	Economic factor
a_3	Population factor
a_4	Government support Factor
p_1	Proportion of influence of Vehicle volume factor =0.1
p_2	Proportion of influence of Economic factor = 0.6
p_3	Proportion of influence of Population factor = 0.25
p_4	Proportion of influence of Government support Factor =0.05

We consider $P = 0.4$ as an distinguish line, if $P > 0.4$, then it is not appropriate to continue prompting the EV into that country right now. But if $P < 0.4$, there are two more cases, when $0.25 < P < 0.4$, we need to build the charging station first, and attract more people choose to buy EVs. But as for $P < 0.25$, we may need to prompt EV first, and then increase the number of charging stations comply with EV market changes.

Now we apply models to America, Ireland and China.

6.1 America

US Transition Prediction

First, we provide US government a plan to do transition from gas cars to E-cars.

According to data of E-car sales in US from 2014 to 2017, we plot a graph to display the increasing of E-car sales. And we formulate a model from the data: S represents sales of Tesla in US per year, and y represents years after 2000(ex. $y = 30$ represents year 2030):

$$S = 160.1 \times 10^{0.1487 \times y}$$

Nowadays the total number of gas cars in US is 111490611, sales of cars per year in US is 6790674. We use the formula above to predict how long it will take US for there to be 10%, 30%, 50%, 70%, and finally 100% electric cars.

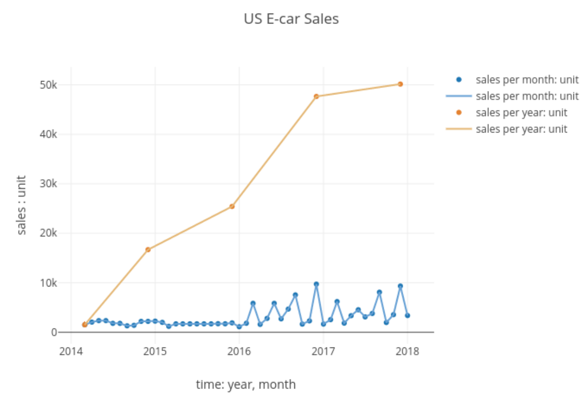


Figure 13: US E-car Sales

percent of electric cars in US		
year	current total number of electric cars	percent
2017	138870	1.25%
2031	22432613	10%
2035	88381788	30%
2036	124488782	50%
2037	175338826	70%
2038	246951737	100%

Need of Charging Stations

Since our model is based on specific situations of America, we directly apply the model here.

At a certain time in the future, all the gasoline vehicles are substituted by the electric cars. Among the research, we found that the GDP in US is 19.64 trillion and based on the previous model,which is

$$S(E, C) = 2e^{E\times n} sin\left(\frac{C}{F}\right)$$

and

$$D(E, C) = 2e^{E\times n} cos\left(\frac{C}{F}\right)$$

the constant coefficient F in US for the destination charger is 200, and that for supercharger is 1000, and$n$ for US is 3. We can conclude that the total charger stations needed is $S(E, C)$ + $D(E, C)$=33.82 million stations. Among 33.82 million stations, about 47% of them is supercharger and 53% of them is destination charger. If we characterize the terms "urban", "suburban" and "rural area" with the the population in certain area. Specifically,

$$Area = \begin{cases} Urban, & \text{if } Population > 50000 \\ Suburban, & \text{if } 2500 < Population < 50000 \\ Rural, & \text{if } Population < 2500 \end{cases}$$

According to the distinguish method provided above, in the urban and urban cluster area of US, there are 434 supercharger stations, which is 48.65%. In the suburban area of US, there are 65 supercharger stations, which is 7.40%. In the rural area of US, there are 392 supercharger stations, which is 43.95%.

US Transition Plan

We have calculated number of supercharger stations and destination charger stations based on nowadays American vehicles volume. Combining the prediction of E-car development, we could form a more comprehensive transition plan for US government.

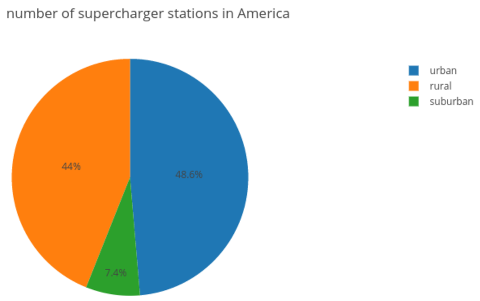


Figure 14: US supercharger stations proportion

plan of building charging stations in US						
year	2017	2031	2035	2036	2037	2038
required num of charging stations(: million)	33.82	59.96	66.61	67.84	68.75	69.22

US Investment Plan

$$P_{us} = \sum_{n=1}^{4}(a_n \times p_n) = 1.25\% \times 0.1 + \frac{8}{185} \times 0.6 + \frac{145}{185} \times 0.25 + 0 \times 0.05 = 0.23$$

Since $0.23 < 0.25$, US is a developed country and E-car in the US is already a mature product, so we suggest US government supports the development of charging stations along the E-car market.

6.2 China

China Transition Prediction

According to data of electric car sales in China from 2014 to 2017, we plot graph to display the increasing of E-car sales. And we formulate a model from the data: S represents

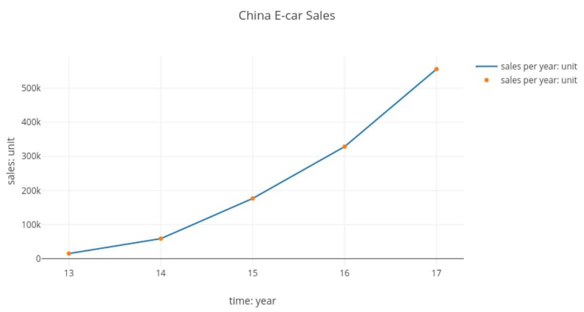


Figure 15: China

sales of Tesla in US per year, and y represents years after 2000(ex. $y = 30$ represents year2030):

$$S = 505.5 \times e^{0.4233 \times y} - 1.168 \times 10^5$$

Nowadays total number of gas cars in China is 217000000, sales of cars per year in China is increasing. We get relation between total sales of car per year and year from data from 2009-2017, which is

$$TS = 2.968 \times 10^7 - \frac{1.286 \times 10^9}{y^2}$$

And then we use the formula above to predict how long it will take China for there to be 10%, 30%, 50%, 90%, and finally 100% electric cars.

percent of electric cars in China		
year	current total number of electric cars	percent
2017	1134856	5.23%
2025	56012576	10%
2027	132706772	30%
2029	311846143	50%
2030	477240313	90%
2031	729857495	100%

Need of Charging Stations

And when it comes to 100%, the number of the charging station needed in China according to previous equation is $2.59 million$, with the factor that $F for supercharger = 1000$ and $F for destination charger = 200$, and $n = 20$, and about 49% of it is supercharger and 51% is destination charger.

We try to apply US distribution of supercharger stations in rural, suburban and urban in China. There are 31 provinces in mainland China, we select three representative provinces – Jiangsu, Shanxi and Gansu Provinces to see if the relation between population and charging stations in China is similar with that in America.

We count number of charging stations in different cities of these provinces and plot a graph. In Figure 16, the red line represents Jiangsu Province, the green line represents Gansu Province, and the blue line represents Shanxi Province.

We could not see any obvious relations between number of charging stations and population in an area, even after we combine data from three provinces and ignore the most abnormal information from the data. So, we conclude that the relation between the number of charging stations and population in China is different from that in America. And we cannot directly apply the model we used on US.

China Transition Plan

But we still could provide an overall transition plan. We have calculated number of charging stations required based on nowadays Chinese vehicles volume. Combining the

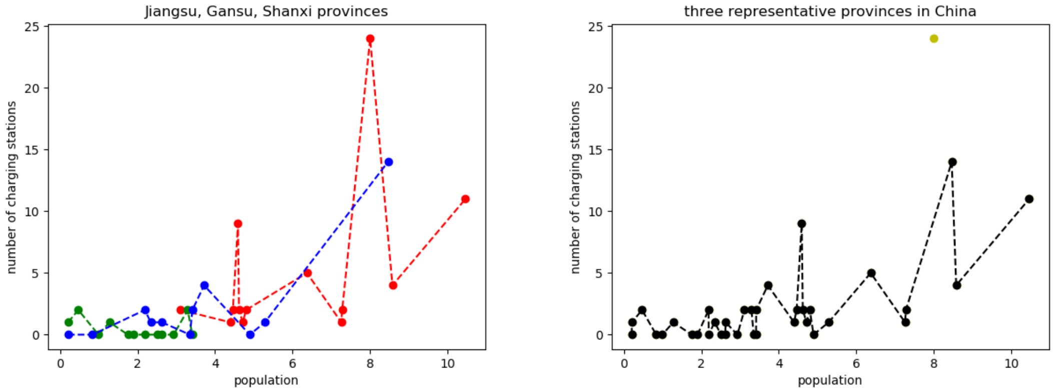


Figure 16: distribution of charging stations in China.

prediction of E-car development, we could form a more comprehensive transition plan for Chinese government.

plan of building charging stations in China						
year	2017	2025	2027	2029	2030	2031
required num of charging stations(: billion)	2.59	4.73	5.27	5.69	5.80	5.81

China Investment Plan

$$P_{china} = \sum_{n=1}^{4}(a_n \times p_n) = 5.23\% \times 0.1 + \frac{74}{185} \times 0.6 + \frac{11}{185} \times 0.25 + 0 \times 0.05 = 0.26$$

$0.25 < 0.26 < 0.4$, China is a developing country and E-car in the China is still a new product. If Chinese government invest charging stations first, then sales E-car will increase very fast, and the transition may be completed even earlier than developed countries.

6.3 Ireland

Ireland Transition Prediction

Ireland has similar conditions as Europe. According to data of E-car sales in Europe from 2014 to 2017, we plot graph to display the increasing to sales. And we formulate a model from the data: S represents sales of E-cars in Europe per year, and y represents years after 2000(ex. year 2030 represents $y = 30$):

$$S = 160.1 \times 10^{0.1487 \times y}$$

Total number of gas cars in Europe in 2015 is 323584629, sales of cars per year in Europe is 6790674. We use the formula above to predict how long it will take Europe for there to be 10%, 30%, 50%, 70%, and finally 100% electric cars.

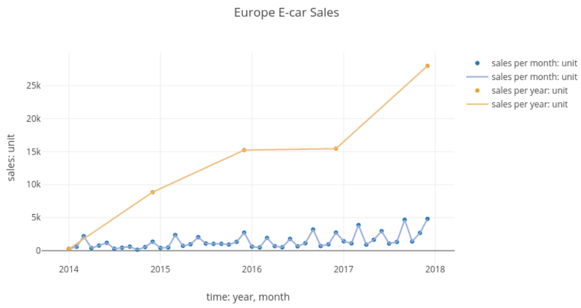


Figure 17: Europe E-car sales

percent of electric cars in Europe		
year	current total number of electric cars	percent
2015	70017	0.2%
2034	62766833	10%
2038	246975207	30%
2039	347828790	50%
2040	489862467	70%
2041	689890716	100%

Need of Charging Stations

In order to prompt the electrical vehicles to Ireland, we need to analyze how many chargers stations are needed in Ireland first. Based on the previous model, we use $F = 10^5$ for supercharger, and $F = 191$ for destination charger, and $n = 3$ and the total amount of charger that Ireland should build is 153 thousand charging stations. And among these, about 86% of the chargers are superchargers and 14% are destination charger.

Ireland Transition Plan

We have calculated number of charging stations required based on nowadays vehicles volume in Ireland. So, Ireland government should always build charging stations at least 7.7% of its total number of cars.

From Figure 18, we can see that number of charging stations is in direct proportion to population. So we could apply model of US on Ireland case.

plan of building charging stations in Ireland						
year	2015	2034	2038	2039	2040	2041
required num of charging stations(: thousand)	3.06	15.3	45.9	76.5	107.1	153

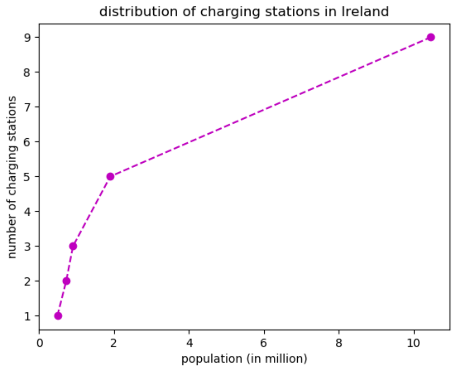


Figure 18: distribution of charging stations in Ireland

Ireland Investment Plan

According to the evaluation model provided above, we can calculate the coefficient that determine the evaluation of prompting the Tesla to Ireland is

$$P_{ireland} = \sum_{n=1}^{4}(a_n \times p_n) = 0.04\% \times 0.1 + \frac{6}{185} \times 0.6 + \frac{116}{185} \times 0.25 + 0 \times 0.05 = 0.17$$

. Since it's smaller than 0.25, we can say that it's worth to do the promotion in Ireland and we should prompt the Tesla vehicles and then build the charging stations comply with the change of market of E-car.

7 Future Expectation

As technology continuously develops, many new transportation options will appear. Some of them have been shown in films and TV series, like ride-share services of electric cars in black mirror(a TV series). Also, Tesla has already studied and is selling self-driving cars(Model S and X).

These new transportation options will change our models of calculating the optimal number and design of distribution of destination charger stations and supercharger stations.

With ride-share services and rapid battery-swap stations, the need of destination charger stations will decrease because people could simply get another battery or another car with full electricity.

8 Conclusion

8.1 Strengths

- **Applies widely**
  Since we have considered comprehensively many key factors of E-car growth, in-

cluding economical and geographical factors, a large amount of countries all over the world can apply our model.

- **Technical supporting**
  We use different methods to support our work, and our model is data-based, using a lot of programming processes to calculate formulas and plot graphs.

8.2 Weakness

- **Inaccuracy**
  We use data from different resources, the data may vary along time (ex. price of chargers). And we are lack of some significant data (ex. total number of cars in Ireland), so our plan is still not detailed enough.

- **Simplifying assumptions**
  To simplify our model, we do not consider some external factors, like economical crisis may limit sales of E-cars.

References

[1] https://www.statista.com/topics/760/united-states/

[2] http://www.stats.gov.cn/

[3] http://www.cso.ie/en/index.html

[4] https://www.usa.gov/statistics

[5] https://www.tesla.com/

[6] http://carsalesbase.com/

[7] http://news.bitauto.com/hao/wenzhang/610892

[8] http://cn.knoema.com/nwnfkne

[9] http://www.simi.ie/Statistics

[10] https://www.usgovernmentspending.com/gdp_by_state

Appendix

We use the python to calculate the P and the link of our code is showed below:

https://repl.it/@onecontestteam/025lessPless04

If $P > 0.4$, we suggest you do not rush to the transition yet. .If $0.25 < P < 0.4$, please use the file above to calculate your optimal date of gas vehicle ban. And if $P < 0.25$, use the file below:

https://repl.it/@onecontestteam/Pless025

Promotion of Electrical Vehicles

Exhausted gas from gasoline vehicles threatens people's health, and cost of air pollution regulation and mining oil fields governance also obstruct development. Developing the market for the electric car is necessary in current society.

Benefits of Electric Vehicles

Environment

Concentrate the pollution to power factory will reduce pollution in cities and improve residents' life quality.

Economic

Cost of using EV will be lower than using gasoline cars, because cost of electricity is much lower than cost of gasoline to drive the same distance.

Key factors required Consideration

Actual cost for supporting use of EV

To satisfy the daily demand of repairing, powering, and other service related to EV, cost of building enough charging stations, installing attached wires and electrical substation, repairing station, and other devices need to be considered thoroughly.

Potential economic problems

As the transition to EV proceeds all over the world, not only countries relying on trade of gasoline may face transformation of economic structure, residents in your country lived on gasoline may lose their jobs.

How to take action

You have to make bad effects of introducing EV as less as possible.

Please first study basic information of your country, use our ultimate model and classification system to classify your country and implement corresponding growth plan.

Follow our examples, study sales of EV and gas-cars in your country and use the tool in Appendix to create a reasonable time line. We suggest you to set a gas vehicle-ban when there are $95\% - 98\%$ electrical vehicles.