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T3 ________________	Problem Chosen	F3 ________________
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2018

MCM/ICM

Summary Sheet

In order to identify whether Tesla is on track to permit a complete switch to all-electric in US, we use **cooperation model** and **exponential fitting model** to fit and predict the future Tesla sales and use **linear regression model** to fit and forecast the future total number of electric vehicles (EVs) if all-electric is achieved. We obtain results by comparing these two numbers at the same time node.

To obtain the final number of charging stations or outlets, we transfer the total gasoline consumption to electricity of same effectiveness based on the **conservation of energy law**. By considering the electricity charging efficiency, we get the optimal number of chargers. Then we analyze the transportation network and the **traffic volume** in urban and rural areas to determine the distributions of stations.

To decide the building sequence, city first or rural first or mix; the cause-and-effect relationship, whether charging stations leads to the increment of EVs or the number of EVs results in the increase of stations; the timeline for the full evolution to all-electric, regarding different percentages of EVs on the specific country's roads; the classification system worldwide, containing geographies, population density distributions, and wealth distributions factors, we consider the **diffusion of innovation theory** then implement it using **Agent Based Model** (ABM). ABM has three factors: economy factor, population factor, and geographic factor. In our research, these factors are respectively wealth distributions with diverse mean and different variance, **reservation price**; social network, using **small world model**; and **urbanization rate**, calculated by urban population divided by total population. Key factors to shape the development plans various corresponding to different purposes. However, the common point is that wealth distribution of a country plays a major part on the way to achieve those purposes.

Contents

1 Introduction

1.1 Background

Triggered by the environmental problems caused by fossil fuels and their unsustainability, there has been a growing needs for the adoption of new clean energy, such as electric and hydrogen. Although vehicles consuming these energies have a fuel capacity with high efficiency, a main obstacle is their interdependence on the charging stations.[1] Thus, an estimation of charging demands is quite essential for the manufacturers in planning the initial and future network. In the following, we pay our interests to the development of electric vehicles in the US and other nations.

Tesla, a company producing electric cars, has gained a number of preorders in the waiting lists. Government policies act as a pivotal role in accelerating the all-electric transformation. Some countries, including China and US, aim to forbid conventional vehicles in the coming years. However, this is not a simple transformation on both producers' and users' sides. In terms of customers, they need time to gradually accept the innovative technologies and make the purchases. Also another key aspect for this ideal to be realized is a mature charging network with sufficient outlets nationwide . To some degree, those two progresses interferes each other.

1.2 Restatement of the Problem

By exploring the current and growing network of Tesla charging stations, we are expected to identify whether Tesla is on the way to permit a thorough change to all-electric in America. If all-electric era comes, deciding the final network of charging stations, including the number of the stations and distributions in urban and rural areas, is our duty.

For further exploration, based on the information of a specific country among South Korea, Ireland, and Uruguay we are required to determine an optimal network of charging stations in the country and demonstrate how we implement the plan to construct it, assuming an overnight change to all-electric. Then we need to decide the policy, where to develop first (city, rural or mix) and the cause-and-effect relationship between buying an electric car and building a station. According to our growth plan, we are supposed to provide a detailed timeline for all-electric in the country and corresponding key factors to shape the plan.

After analyzing all tasks mentioned above, we need to consider more sophisticated cases containing different geographies, population density distributions, and wealth distributions of different countries. A classification system need to be created to deal with the growth model of charging stations in different "kinds" of countries.

Technology development also has impact on our analyses of the increasing use of electric vehicles, because more transportation options appear. To comment on this situation is our task. Finally, a one-page handout for leaders of different countries over the world who are in an international energy summit is needed. It must include the key factors on developing all-electric plan and a suggested gas vehicle-ban date.

2 Model preparation

2.1 Assumptions

For our model, there are several assumptions here:

- The scale of charging stations is not restricted by geographical and environmental conditions. Each station could be able to supply sufficient energy according to the demand.
- In one station, the number of charging outlets could range from 5 to 100.
- We assume the idle rate of charging outlets to be around 50 per cent.
- In a super charge station, one can move his electric vehicle after charging over 60 per cent quantity of electricity. When the vehicle gets fully charged, drivers should leave instantly and not occupy the parking space.

2.2 Definitions and Variables

Parameters

a,b,c,d - coefficient of interaction term

r,s,u,v - intrinsic growth rate

K,L,M,N - environment capacity

x - the number of Tesla vehicle delivery

y - the number of charging stations or outlets

z - the number of traditional cars

m - the number of electric vehicles

n - the number of other transportation options

t - time

μ - average reservation price

σ - standard deviation of reservation price

3 Fitting and Forecasting Model

To identify whether Tesla has ability to allow a complete switch to all-electric in America, we collect annual sales data of Tesla in 2012-2017:

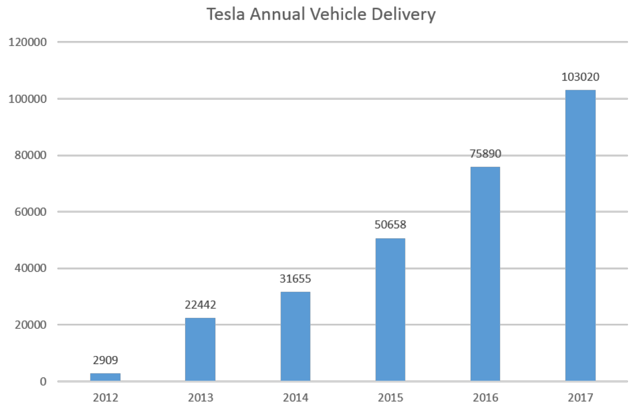

Figure 1: Tesla Annual Vehicle Delivery [2]

From these statistics, we can discover that growth rate is increasing especially for 2015,2016,2017. In this case, we search for quarterly sales statistics for these three years to do a fit process. The detailed data for three years are as below:

Tesla Quarterly Sales

Time Index	Year	Sales
1	Q1 2015	10123
2	Q2 2015	11532
3	Q3 2015	11603
4	Q4 2015	17400
5	Q1 2016	14820
6	Q2 2016	14370
7	Q3 2016	24500
8	Q4 2016	22200
9	Q1 2017	25000
10	Q2 2017	22000
11	Q3 2017	26150
12	Q4 2017	29870

Figure 2: Tesla Quarterly Sales [2]

At first, we consider the relationship between a Tesla car and a charging outlet is cooperation, because the appearance of a Tesla car can increase the number of charging outlets and the increment of charging outlets can be along with an increase of Tesla sales. Hence, the fit model we choose is the cooperation model. Differential equations for the cooperation model shows below:

$$\frac{dx}{dt} = rx(1 - \frac{x}{K}) + axy \tag{1}$$

$$\frac{dy}{dt} = ry(1 - \frac{y}{L}) + bxy \tag{2}$$

To simplify the complex calculation process, it is reasonable to regard the fit model as an exponential model for their differential equations are similar and the exponential model is a conservative choice because of a slow increasing rate. So the simplified exponential fit model is:

$$x = ae^{bt}, \quad where \quad a = 10300, b = 0.08842, R^2 = 0.8434 \tag{3}$$

Fitting graphs are following:

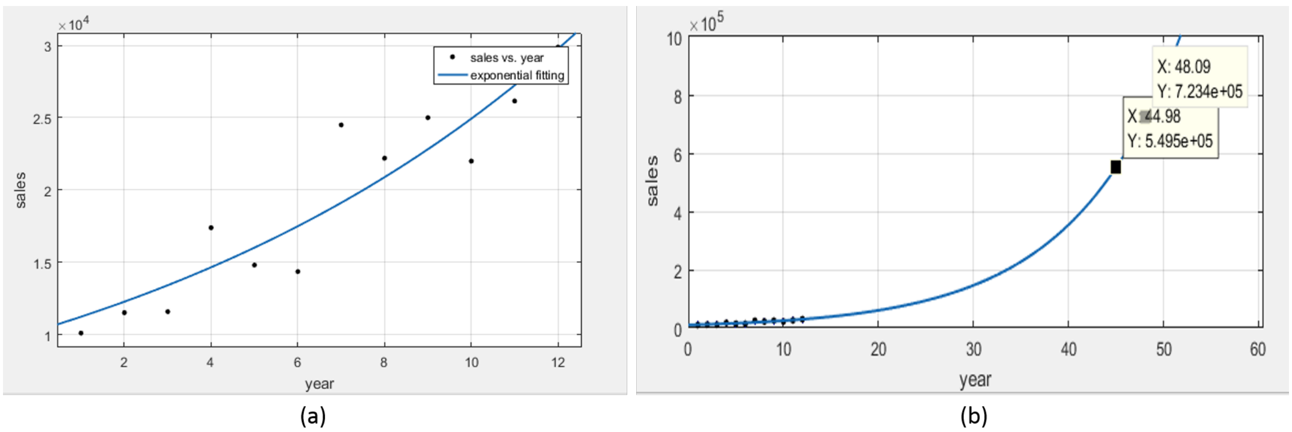

Figure 3: Fitting Model for Tesla Sales

Graph (a) shows the fitting curve in the range of 2015-2017. Using this fit model we can easily obtain Tesla sales statistics in 2025. The reason for choosing 2025 as a time node is that by using limited statistics we can predict a short range of years in the future. Graph (b) exhibits the prediction for Tesla quarterly sales in 2025 by the fitting model and clear results are in the following table:

Tesla Sales Prediction for 2025

Time Index	Year	Predicted Sales
45	Q1 2025	549,400
46	Q2 2025	602,300
47	Q3 2025	660,100
48	Q4 2025	723,400
Total	2025	2,535,200

Figure 4: Tesla Sales Prediction for 2025

The criteria to decide whether Tesla is on track to allow a complete all-electric in US is to compare the number of traditional cars if electric vehicle would not appear and the number of Tesla accumulated sales. If the number of Tesla accumulated sales is approximately equal to the number of traditional cars in the same time node in a relative short range of future years, then we consider that Tesla is on the way. Otherwise, Tesla might not be able to allow a thorough switch in US. The number of traditional cars can be the final number of electric vehicles if all traditional cars can be replaced by electric vehicles. After fitting and predicting for Tesla sales, to fit and predict the number of traditional cars is our duty. When collecting data, we detect that the statistics of the numbers of traditional cars in 2012-2016 form a straight line. Therefore, we choose a linear regression model to fit and forecast. Data and results are here:

Time Index	year	passenger cars
1	2012	169,092,667
2	2013	170,584,000
3	2014	173,566,667
4	2015	175,740,000
5	2016	179,199,333
14 (predicted)	2025	194,318,396

Figure 5: The Number of Traditional Cars

$$z = A + Bt, \quad where \quad A = 1.69 \times 10^8, \quad B = 1815953 \tag{4}$$

From Figure 4 and Figure 5, we can recognize that those two numbers in 2025 are not in the same scale. Hence in 2025, Tesla can hardly achieve the goal. We continue to compare and find that if our forecast models are available then those two numbers will be equal to each other around 2042. However, for the following two decades, Tesla sales can be resisted by other competitors or by its own environment capacity. Thus, in conclusion, Tesla is on the way to allow a complete switch, but it will never achieve the goal if it does not experience a breakthrough.

4 Conservation of energy model

In the US, there is an increasing tendency for traffic volumes on roads. Due to the conservation of energy law, no matter the individual travel are done by conventional cars or the replaced electric vehicles, the outputs of electricity should still satisfy peoples' daily demands. In other words, electricity should replace the status of gas with the same effectiveness in car traveling miles. Based on this, we could then by estimating the number of outlets and stations nationwide to design a network.

Assumptions

- Assume that American population and travel habits do not have dramatic change from 2012 to 2025.
- Assume that American people living standards maintain a steady improvement from 2012 to 2025.
- Assume the American fuel resource is still sufficient in the near future.

4.1 Fuel demand and traffic volume prediction

Analysis of traffic volume data

Based on the traffic data from US Department of Transportation[4], an American traffic volume table could be shown below:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total year
2010	221	211	254	254	257	260	265	264	245	256	240	240	2966
2011	224	213	253	250	254	258	260	261	242	252	239	241	2947
2012	228	218	256	249	261	260	260	264	239	254	240	245	2975
2013	229	216	253	252	263	260	264	268	243	259	240	239	2986
2014	226	214	253	257	266	263	270	269	248	265	241	241	3015
2015	233	217	258	263	271	271	278	272	255	268	249	252	3088
2016	237	229	270	268	275	277	281	279	262	272	259	262	3172
2017	242	233	272	272	281	281	284	283	263	275	261	264	3211
Month total	1841	1752	2070	2065	2129	2131	2163	2161	1995	2101	1969	1984	24359

Figure 6: vehicle miles on all roads and streets in the US

Then, we can get a traffic volume trends depicted as follow:

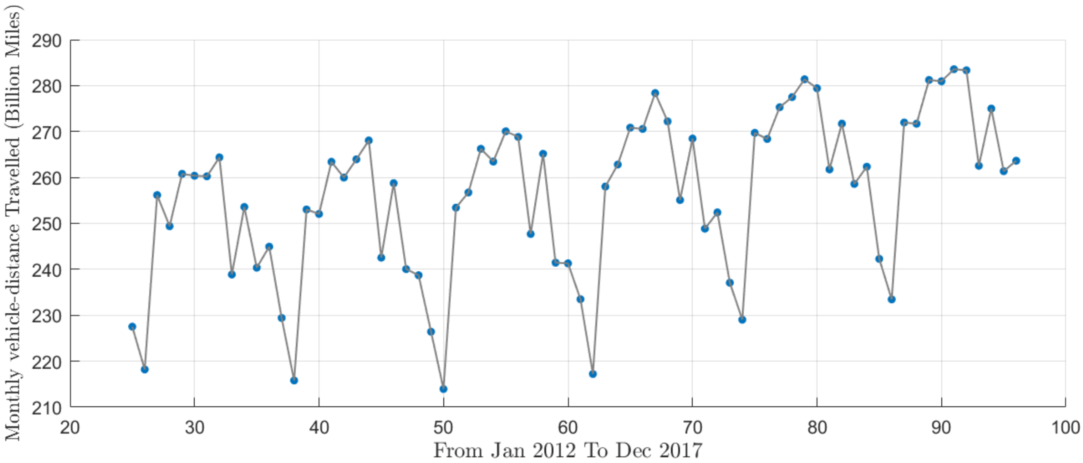

Figure 7: travel trends in the US

From the figure above, we could easily find that traffic volume per month from 2012 to 2017 fluctuates up and down with a seasonal pattern but show an overall increase for on a yearly basis. The traffic volume is relatively high in summer and low in winter.

Forecasting results and conclusion

Based on the data trends in the last step, we decide to choose the linear regression model with a seasonal pattern to forecast the future volumes.

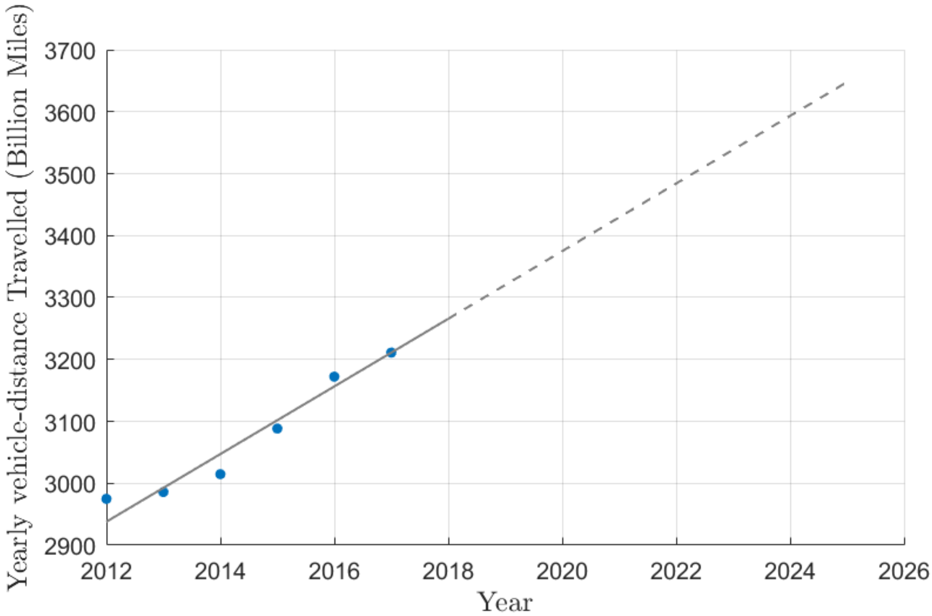

Figure 8: yearly vehicle miles in the US

Use the yearly data from 2012-2025, we could compute A and B coefficients to fit the regression model $X = A + Bt$. Precisely, A $\approx -1.0694 \times 10^5$ and B ≈ 54.6109. The predictions for the coming years approximately follow this formula

$$\textit{yearly travel miles in billions} = -1.0694 \times 10^5 + 54.6109 \times \textit{year} \tag{5}$$

Thus, in 2025, the predicted traffic volume is about 3.6479×10^3. Now we have obtained the predicted data for 2025. The next step is to calculate the seasonal factor for each month so that we could generate the pattern for the whole 2025.

2010-2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Month	1841	1752	2070	2065	2129	2131	2163	2161	1995	2101	1969	1984	24359
Month/Year	7.56%	7.19%	8.50%	8.48%	8.74%	8.75%	8.88%	8.87%	8.19%	8.62%	8.08%	8.14%	100.00%

Figure 9: seasonal factor for each month

The reason why we compute the miles in month is to better estimate an upper daily demand of fuel consumption. In order to satisfy the maximum demand in summer, we choose the month with largest traffic volumes to calculate a adequate daily demand for the country, which is July with a seasonal percentage of 8.88%. Therefore, monthly miles in July 2025 would be $3.6479 \times 10^3 \times 8.88\% = 3.239 \times 10^3$ billion miles so the daily travels approximates 104.5 billion miles.

Among the 104.5 billion miles, some are in rural areas and others are in urban. In the raw data, the system is divided into 6 parts: rural interstate, rural other arterial, other rural, urban interstate, urban other arterial and other urban. We separate them into two categories: city(urban other arterial and other urban) and highway(rural interstate, rural other arterial, other rural and urban interstate). Generally, vehicles running in city with a lower speed so same miles of travel consumes more oil. Vehicles running on highway with a higher speed consumes less oil.

4.1.1 Energy equivalent conversion model

Due to the heavy weight of American cars, conventional car consumes large amount of gas. According to statistics of the US Department of Energy, vehicles average oil consumptions in the US are about 21 MPG in city and 29 MPG on highway. But for Tesla Model 3, the efficiency is highly increased, which is about 136 MPGe in city and 123 MPGe on highway.[?]

With the daily travels(104.5 billion miles) obtained from the last section, we times an average percentage concluded from history data to divide it into city(53.3 billion miles) and highway travels(51.2 billion miles).

Next, an important step, if all conventional cars are replaced with electric vehicles, we convert the travel miles to the Tesla consumption of electricities as an representation for EVs.

$$\text{for city: } \frac{53.3 \text{ billion miles}}{136MPGe} = 3.9 * 10^8 \text{ Gallon electrics} \tag{6}$$

$$\text{for highway: } \frac{51.2 \text{ billion miles}}{123MPGe} = 4.2 * 10^8 \text{ Gallon electrics} \tag{7}$$

4.1.2 Estimate number of chargers and stations

Serving abilities of superchargers and destination chargers

As we already know, supercharging could provide a an up to 170 miles of range in 30 minutes of time. If we assume a supercharger works 10 hours a day, it could serve no more than 16 cars per day to travel 3400 miles in total. Destination charging needs several hours or even overnight to get a car fully charged. Tesla has an endurance of 310 miles. Thus, a destination charger could serve at most 3 cars per day to travel 930 miles in total.

Due to these characteristics, supercharging is utilized more in longer road trips while destination charging could be more suitable for city daily travel. Therefore, we choose supercharge stations for highway and destination charge stations for city.

Estimate the lowest numbers

As computed before, we have an daily demand in city of 53.3 billion miles and highway travels of 51.2 billion miles. Combine these data with the serving abilities of 2 different chargers: supercharger(2720 miles per day per charger) and destination charger(930 miles per day per charger).

$$\text{number of superchargers: } \frac{51.2 \text{ billion miles}}{3400 \text{ miles per charger}} = 1.51 * 10^7 \text{ chargers} \tag{8}$$

$$\text{number of destination chargers: } \frac{53.3 \text{ billion miles}}{930 \text{ miles per charger}} = 5.73 * 10^7 \text{ chargers} \tag{9}$$

At present, American has an overall highway length of 127,724 miles. Considering the endurance of EVs, stations should be built at least every 100 miles on those highways, so about 1500 supercharger stations are a minimum standard. Taking the scale of stations and heavy traffic flows into consideration, even more could be built to satisfy people's demand.

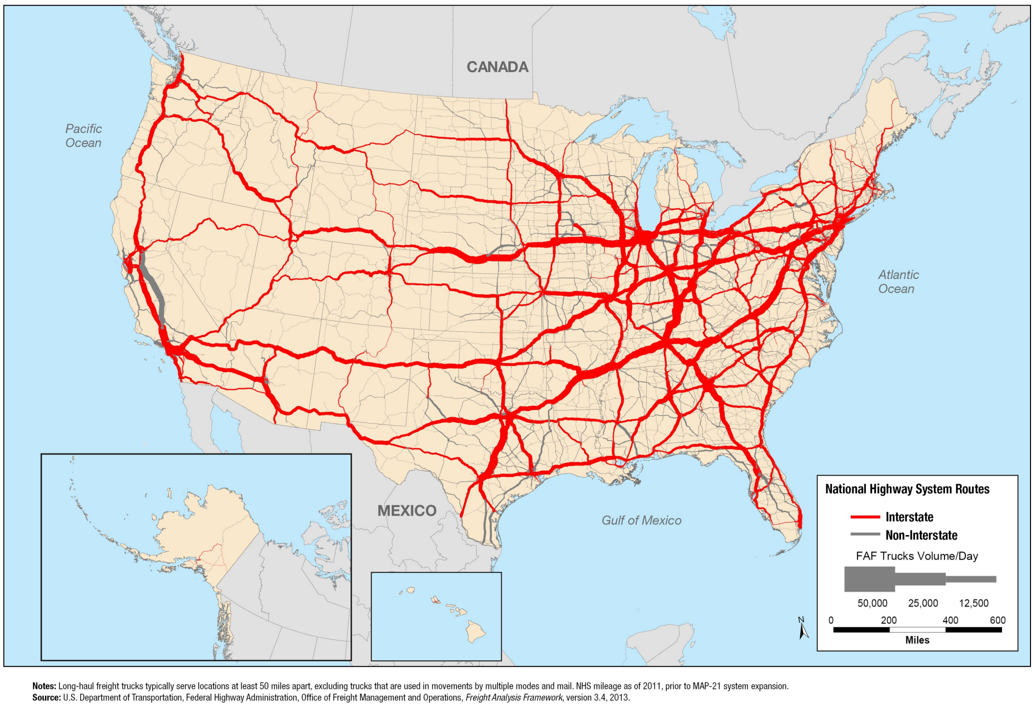

Figure 10: traffic network of American[3]

The stations' network would be quite corresponding to the traffic network, superchargers are distributed along the main highway. The larger the traffic volume on a highway, the more and closer stations would then be built. Destination chargers will concentrates on cities with higher population density and higher urbanization area where is also the main sales market of EVs.

4.2 Agent Based Model

To capture the characteristics of charging station network evolution in Ireland, we employ Agent-Based model (ABM) to simulate the diffusion of electrical vehicles. In this context, agents are individuals who will make decisions of whether adopting innovation, i.e, EV. Apart from numerous agents with their individual attributes, the ABM we use is composed of environment, interaction topology, learning rules and decision-making heuristics.

- Individual. Individual attributes including innovativeness, reservation price, position in grid. For innovativeness, it is preserved to be five adopter categories including 2.5% innovator, 13.5% early adopters, 34% early majority, 34% later majority, 16% laggards. Therefore, to simplify our model. Different categories imply different preference to new technology. As for reservation price, this parameter represents the relative advantage the customers conceive, according to Hu etink et. al (2010), this should follow a lognormal distribution $\theta \approx exp(\mu, \sigma)$. However, in our model we synthesize those two parameters by assuming the reserved price is normal distributed with μ at EV price and $\sigma = 1$. Position in grid is used to compute the relative nearest distance between a customer and a charging station. The nearest target is found by breadth-first algorithm (BFS). Once the distance exceeds the tolerance distance, customers would not consider to purchase an EV.

- Environment. For sake of simplicity, a 400 by 400 square grid is used to represent Ireland. The cell of the grid contains at most one EV potential customer. The simulation world is evenly divided into two regions, urban area and rural area by a vertical line, as illustrated by the image below. The 400 by 200 urban area, located at the right half of the grid, is more densely populated while the left half, namely rural area, has lower population density (this simplification is made according the the characteristics of Ireland population map, which will be found in the appendix). In urban area, 60% out of total 100000 potential EV customers are randomly assigned within this region, the rest 40% of population is randomly distributed to rural area, according to urban-rural population, 3:2 in Ireland (**source, unicef**). Beside potential EV customers, EV charging stations are also located in the grid. The growth of charging stations is determined by the equation ??? we proposed above, with exponential annul growth, however, different distribution strategies in two regions will be tested, whose result will be discussed in Results section.

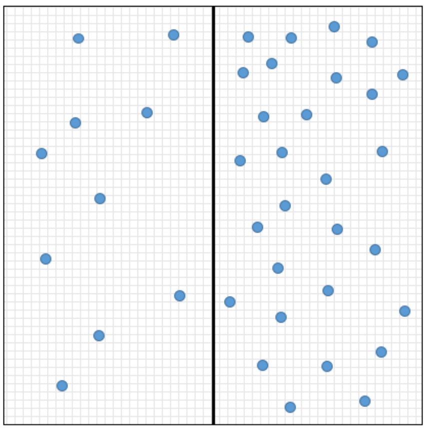

Figure 11: ABM Grid

- Interaction topology. The social network structure here is modeled by Watts–Strogatz model[5]. In Watts-Strogatz model, which is also known as small world model, social network is initialized as a lattice, where each node is connected to all it's neighbors. By going through each node, the edges between each node and it's neighbors will be relinked to an arbitrary node with probability, p. Short average node distance and high local clustering coefficient are found to coexist in this model, thus, Watts-Strogatz model is believed to capture the essential characteristics of real social network. In our model, each customer will be connected to it's eight nearest neighbors, but with 20% a nearest neighbor link will be replaced by a link to a random node in the grid regardless of physical limitation.

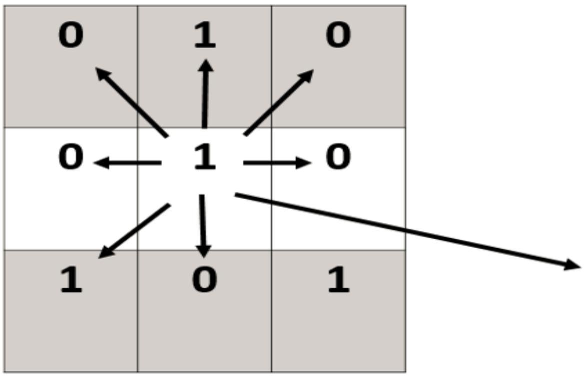

Figure 12: Small World Model

- Learning rules. Learning rules including social learning and technological learning. Then influence of neighbors is measured by sum of number of neighbors who is EV owner divide by total number of neighbors, once this value exceeds the neighbor threshold 0.375, this customer would be motivated by his friends to accept the new invention. Due to technological learning effect on price, we estimate that the price of EV accords with the price decreasing rate of hydrogen car, as proposed by Hu $e$tink et. al (2010)

$$p_t = p_0(\frac{N_0}{N_{t-1}})^{\alpha} \tag{10}$$

  where p_0 represents the initial price of EV. The price of EV decreasing with relation to the ratio of initial number of adopters N_0 to cumulative number of adopters N_{t-1} at time $t-1$. The learning ability α determines the speed of price reduction.

- Decision-making heuristics. There are three factors that determines whether a customer purchase an EV. From economic perspective, the prime concern of a consumer is the price of the EV. By considering comparing the current price of EV with customer's reservation price, customers decide the purchase. The reservation price, which is assumed to be normal here, may vary from country to country due to wealth distribution. By changing the reservation price, we find this factor plays an essential role in shaping the network evolution. The second impact is social network, which is the net result of population distribution, wealth distribution and distance with regard to charging station. The third impact is charging station availability, which is determined by the geographical factor such as the individual is located at urban area or rural area and the charging station network growth strategy. The pseudo code is attached below.

```
if ev_price > resavative_price
        refuse to purchase ev
    exit
else if sum(ev_owner_neighbor)/total_neighbor >
                neighbo_shrehold
        refuse to purchase ev
        exit
else if distance_to_nereast > station_distance_shreshold
        refuse to purchase ev
    exit
else
        adopt ev
    exit
```

To explore the optimal network evolution proposal, we consider our model based on the principle that the yearly growth of charging station number satisfies the energy need of the country to switch to full EV system. In other word, we will build refueling infrastructure first to fulfill the energy demand, then searching for the best strategy of investigating in construction. Given the yearly growth of charging station, we can compute the total number of charging station to be built each year. Although, the exact placement of charging station vary greatly from region to region since the location of interests are different, we distribute different portion of charging stations to urban area and rural area to explored resulting maximum EV owner rate and the time spent to reach the maximum. Then each charging station is placed in random within the assigned region. We tested different ratio of investment strength of urban to rural area, from completely building urban chargers to merely building rural area chargers. We find that mix construction investment with 0.4 in urban leads to the optimal outcome which yields the fasted convergence to the maximum EV owner percentage. Details are given in Results section.

4.3 Kolmogorov's competition model

Technology improves rapidly. Transportation options are increasing which means that the number of electric vehicles can not increase exponentially without resistance. Competitions in the market are fierce. Our former suggested the cooperation model or the exponential model need to be adjusted, adding a resistance factor. Thus, our model for the increasing use of electric vehicles now follows the figure of competition model. Differential equations are:

$$\frac{dm}{dt} = rm(1 - \frac{m}{M}) + cmn \tag{11}$$

$$\frac{dn}{dt} = rn(1 - \frac{n}{N}) + dmn \tag{12}$$

Results By simulating the AGM with parameters of Ireland, we find the optimal investing strength ratio of urban to rural area is 0.4, dominating all the rest candidates, which means we should take the strategy that building both city chargers and rural area chargers will lead to not only the fasted growth speed but also the greatest EV prevalence. Note that x-axis represents the time spend from clean slate, y represents the percentage of EV owner among all drivers. With this strategy, it is possible to switch Ireland to a complete EV system within 15 years.

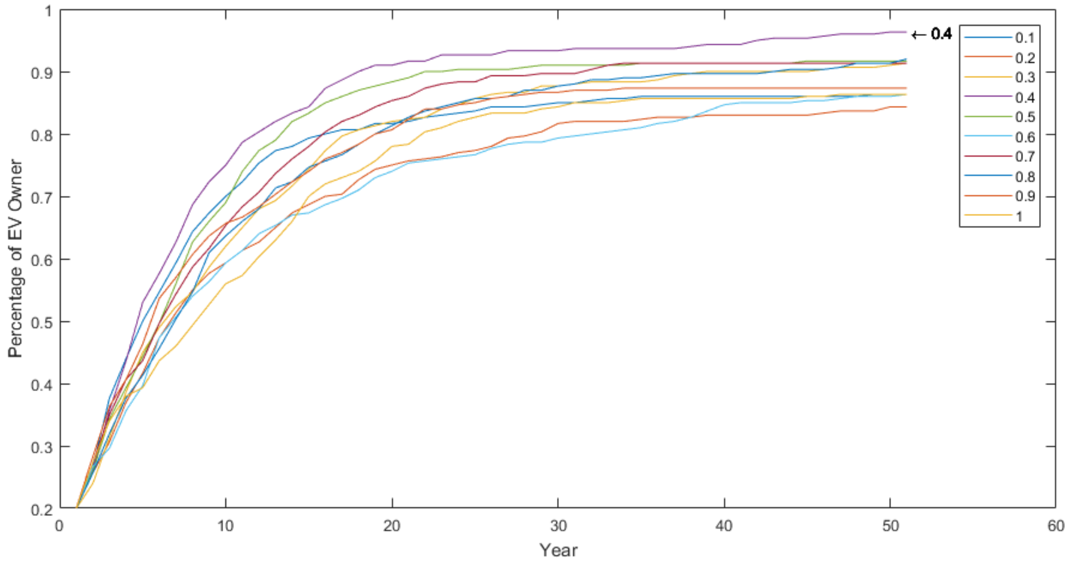

Figure 13: Diffusion of EVs in Ireland

We further demonstrates the heat map of Irish charging network growth, where each red dots represent one charging station distribution at the moment when 30%, 50% and 90% prevalence of EV occurs.

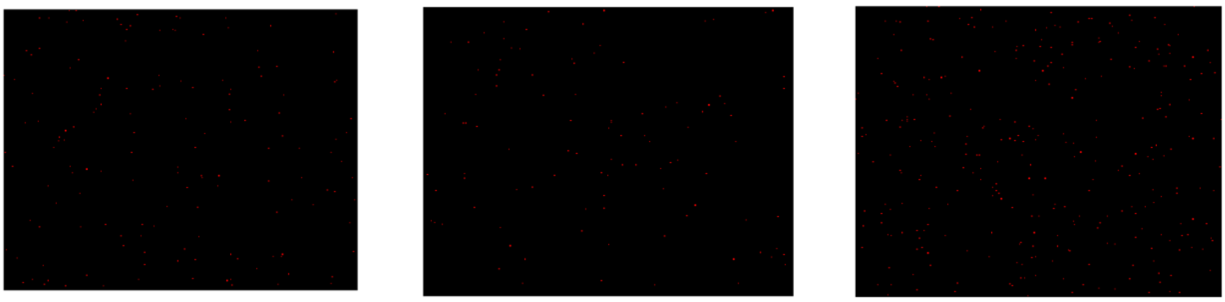

Figure 14: Evolution of Charging Station Network

Based on Ireland model, we changed one of the parameter while maintaining other parameters in consistence to analyze the sensitivity of our model. Parameters changed including reservation price distribution (form $\mu = 0.5$, $\mu = 1$, $\mu = 2$), urban area proportion with respect to the whole grid area and urban population proportion. We find that the wealth distribution is the principle determinant, since with $\mu = 0.5$, the system will collapse leading to the vanish of EV, as illustrated by the figure below.

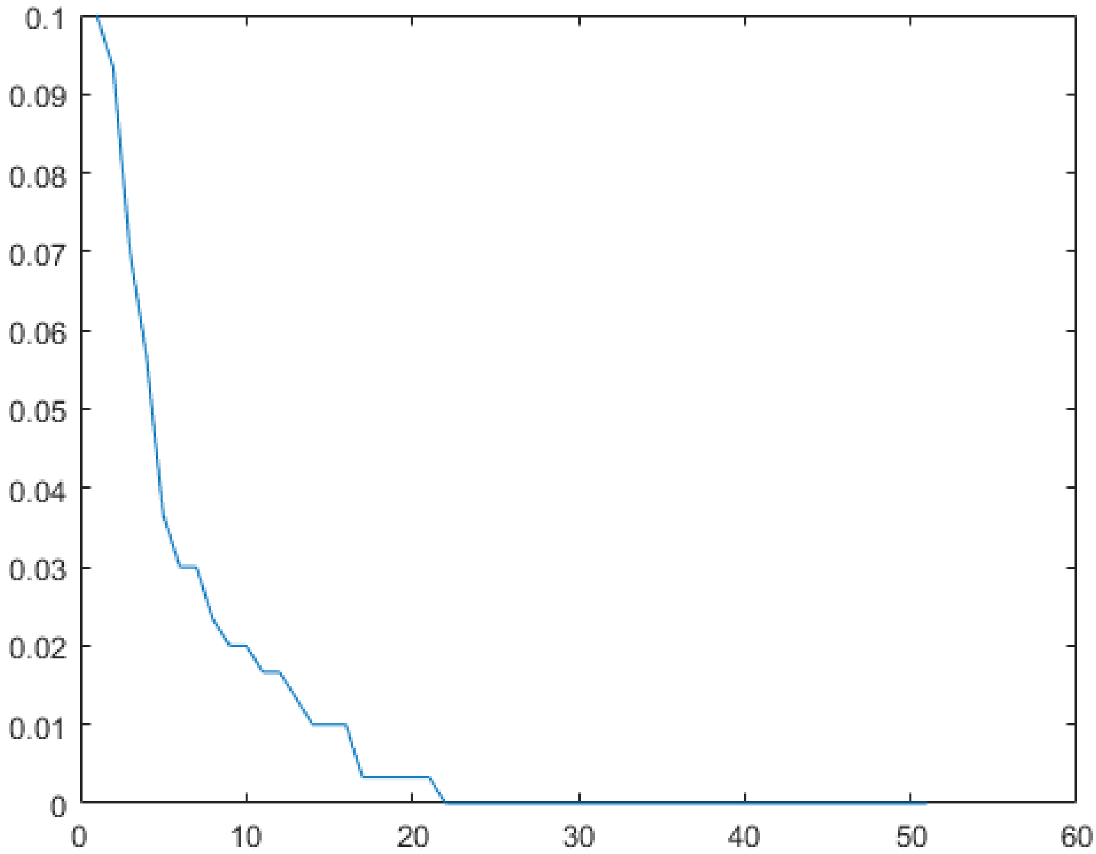

Figure 15: Sensitivity Analysis of μ

Different parameters are categorized into two classes, mixed or urban-first, according to the optimal investing strategy which enable the system to reach 90% EV prevalence in shortest time. The result are shown below.

	Completely Urban(0.8-1)	Mixed(0.2-0.8)	Completely Rural(0-0.2)
Urban Area Proportion	1,0.9	0.8,0.7,0.6,0.5,0.4,0.3	
Urban Population Proportion	1,0.9,0.8	0.7,0.6,0.5	

Figure 16: Classification System

5 Strengths and Weaknesses

5.1 Strengths

- Conservation of energy model starts from the daily travel habits of people. Estimate the demand of electricity facilities from a microscopic view.
- This ABM model is a straightforward model with tunable parameters that can capture most of the factors that the task require us to consider.
- According to this ABM model we can deduce the optimal investment strategy to accelerate the switch to full EV system, which will help alleviate the climate change.

5.2 Weaknesses

- While computing on the national level, travel miles analysis could not cover the traffic networks in a careful way. Roads conditions are quite different and also load volumes distribute with a large disparity.
- There are too many parameters in ABM, which undermines the robustness of the system.
- The random assignment of charging station in ABM fails to

6 Application of our models — a one-page handout for the leaders of countries

Our team has drawn some conclusions in the form of an action plan. We hope that these suggestions will support and accelerate the effectiveness of the Worldwide deployment of electricity vehicles. In order to make full use of the commitment of automakers to electric vehicles and the willingness of energy companies to help build charging stations, it is time for national government to provide leadership. The plan of action is as follows:

The government budget should provide funds for the first phase of electricity vehicles deployment. With national financial participation, a network of up to thousands of charging stations allows up to several thousands of cars to operate freely in the country. The cost sharing of the gas station and the incentive to increase the number of electric vehicles in California can achieve an considerable annual investment.

Cite stations, the establishment of electric car network, are to encourage vehicles and stakeholders to establish partnerships. The successful implementation of the first phase requires cooperation with other stakeholders related to electric interests. Partnerships with energy providers will provide funding and expertise to build fuel stations and open markets for charging stations. The partnership with the vehicle supplier places the vehicle in the proper fleet and helps ensure successful operation. Working with other government agencies will maximize the resources needed to implement the electricity network, including processing codes and standards, and finding and coordinating firefighting officers and security personnel. Public-private partnerships should be established and defined.

Overall, countries should develop their blueprint of electricities of vehicles essentially based on their own national conditions and explore markets in urban and rural area.

7 Further Investigations

- In ABM, different social network structure can be tested to approach the reality, such as scale-free network. Traffic network can also be considered to construct ABG that satisfy the transportation need. Researchers can apply AGM to each prime city and ensemble ABM of each city to get more accurate nationwide estimation.

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