For office use only	Team Control Number	For office use only
T1 ________________	**83183**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**D**	F4 ________________

2018 ICM Summary Sheet

The replacement of fuel vehicles with electric vehicles is coming true in the future. Many challenges will be met by the government when endeavoring to promote the development of electric vehicles, such as the number of charging stations, location and distribution. The improve of purchasing ability of electric vehicles, limitation of the domestic electric vehicle development, and so on. In this paper, fuzzy analytic hierarchy process (AHP), total demand model, logistic growth model, entropy weight evaluation model and grid model of charging station were used to simulate the whole system the center theory, genetic algorithm and greedy algorithm were also employed to provide recommendations for the development of electric vehicles and solutions to the government.

First, the number of charging stations was calculated. The different types of vehicle owners and vehicles, the charging frequency and other variables were firstly considered the demand for charging stations are calculated by estimating the total demand for electric vehicles charging capacity, and then the number of charging stations were determined. For the site selection, grid model, genetic algorithm and greedy algorithm were used to calculate the distribution coordinates according to the weights of the cities, suburbs and rural areas.

Second, Ireland was taken as an example. The above methods were employed to solve the distribution number and location coordinates. We find that the Logistic models are also suitable for vehicle population, it is the Logistic models that address the problems about the establish of charging network, and it also helps us calculate how long it will take for there to be 10% electric vehicles, 30% electric vehicles, 50% electric vehicles, and 100% electric vehicles.

Thirdly, In case of the influencing factorssuch as GDP, state subsidy policy, population density and the influence of charging station on the distribution network, we use the entropy method to weight each variable, and then establish the evaluation model of charging station network erection. The entropy of each index, find the key factors that affect the erection and development of charging network.

Fourthly, external technologies, such as sharing technology, automatic driving and rapid battery replacement all play different roles in stimulating electric vehicles. Super-high-speed rail has played a negative feedback role due to its competitiveness. Therefore, the development trend of electric vehicles may appear as a logistic curve.

To sum up, rigorous model and accurate data calculation were performed, and the development of universal law of electric vehicles and charging network were drawn. It should be very useful to the government for better management of electric vehicles.

Keywords: Genetic Algorithm; the Entropy Weight Method; Logistic Model; Integrated Assessment Model; Charging Network

Contents

Keep Calm and Drive on Electric

Team # 83183

1 Introduction

With the development of society, economical electric vehicles are becoming more and more popular than traditional fossil fuel-based vehicles due to their environmental-friendly characteristic. In particular, Elon Musk recently passed a self-owned Tesla sports car by his SpaceX Falcon rocket into Mars - Earth orbit, which greatly enhance consumers interest in electric vehicles. To promote the transition to electric vehicles, some countries, including China, have already announced that gasoline and diesel vehicles will be banned in the future.

If the petrol car is banned, abundant and convenient charging stations are highly needed. Ideally, all the fuel cars should be converted to electric vehicles. All of petrol stations will become charging stations. It is noteworthy that the replace of traditional cars with new energy vehicles can not be achieved at once, which needs a long period for the replacement.

Thus, we should not only consider the distribution of charging stations in the final case (100% electric vehicles), but also consider changes in the type of car and the charging network. For example, what is the charging network when 10%, 30%, 50%, 90% of electric vehicles are realized? It is important to deduce the final charging structure enable the full use of electric vehicles.

2 Restatement of the Problem

2.1 Problem

Tesla now offers two charge stations: (1) Destination charging designed for charging for several hours at a time or even overnight, (2) Supercharging designed for longer road trips to provide up to 170 miles of range in as little as 30 minutes of charging.

- How many charging stations are needed in the United States if all are switched to electric vehicles and how they are distributed in urban, suburban, and rural areas?
- In Ireland, for example:

a. If all cars become instantaneously electric vehicles, what are the key factors that influence the implementation of the plan?

b. What kind of construction plan will you propose assuming the country has not yet installed a charging station?

c. Based on your plan, when will Ireland be fully electrified.

- Is the program applicable to countries with different geographic locations, population densities and different wealth distribution?
- Briefly describe the future sharing of cycling, autopilot, even hyperloop and other technologies for the development of electric vehicles.
- Calculate the date of setting the ban on petroleum vehicles.

2.2 The Sample Analysis of the Problem

The paper is divided into four parts:

1. First, the number of charging stations was calculated. The different types of vehicle owners and vehicles, the charging frequency and other variables were firstly considered the demand for charging stations are calculated by estimating the total demand for electric vehicles charging capacity, and then the number of charging stations were determined. For the site selection, grid model, genetic algorithm and greedy algorithm were used to calculate the distribution coordinates according to the weights of the cities, suburbs and rural areas.
2. Second, Ireland was taken as an example. The above methods were employed to solve the distribution number and location coordinates. We find that the Logistic models are also suitable for vehicle population, it is the Logistic models that address the problems about the establish of charging network, and it also helps us calculate how long it will take for there to be 10% electric vehicles, 30% electric vehicles, 50% electric vehicles, and 100% electric vehicles.
3. Third, In case of the influencing factors, such as GDP, state subsidy policy, population density and the influence of charging station on the distribution network, we use the entropy method to weight each variable, and then establish the evaluation model of charging station network erection. The entropy of each index, find the key factors that affect the erection and development of charging network.

4. Fourth, external technologies, such as sharing technology, automatic driving and rapid battery replacement all play different roles in stimulating electric vehicles. Super-high-speed rail has played a negative feedback role due to its competitiveness. Therefore, the development trend of electric vehicles may appear as a logistic curve.

3 Assumptions

- Model for Total Demand of Electric Vehicles to Terminals.

  a. Take Tesla Model 3 as an example, when the battery is fully charged, it can sustainably travel 500km. However, during the actual driving, electric vehicle users usually need to reserve a part of the electric power to look for the charging station. Meanwhile, due to regular charging and discharging of batteries. The sustainability will be loss. Therefore, in actual case, the travel distance of battery is reduced to 450km.

  b. Except taxis, the major cares (including: government cars, private cars) mostly select charging piles and slow-charging at homes. Only some of them would choose public charging stations for emergency charging or regular charging. Among them,the ratio of fast charge and slow charge can be determined according to the specific circumstances of the planning area.

  c. Considering the repair and maintenance of carstaxis and other cars, we assume that the use rates of these vehicles are both 95%.

- Charging Station Distribution Net Model

  a. The center is located in a plain area, its population is evenly distributed, and their income levels are similar.

  b. There is a unified transportation system in the central area with the same degree of convenience. And the transportation cost is proportional to the distance. In the grid range, the population distribution, income level and consumption pattern are supported to be the same.

- Logistic model

  a. Electric car production is greater than the number of scrapped.

  b. Electric car accounted for 90% that is completely replace electric car gasoline car.

- Assume that the data is real and effective.

4 Terms, Definitions and Symbols

Symbol	Meaning
W	the total amount
W_A	A type of user's daily demand for charging
W_B	B type of users daily demand for charging
W_{A1}	A1 users daily demand for charging
W_{A2}	A2 users daily demand for charging
W_{AV1}	Electric taxi fast charge capacity, according to the survey average power consumption of 48kwh
W_{AV2}	Other cars fast charge, according to the survey average power consumption of 43kwh
B_{A1}	Average daily recharge times for category A1 users
B_{A2}	The average number of charges per day for category A2 users
a_p	The vehicle's usage rate is 95%
N_0	Number of electric taxi vehicles
N_P	Number of other vehicles
γ_1	Proportion of fast-charging vehicles in other passenger vehicles
W_{Bi}	The average daily demand for Class B users in the i-th small area, the average power consumption was estimated to be 43kwh
N_{Bi}	The number of Class B users in the i-th small area
t_{Bi}	The average charge per day for category B users in the i-th small
N_c	The number of charging stations
ε	A transition factor between charging demand and charging capacity, which is 1.5 in this paper
t	Daily average service time of the charging station; according to the literature combined with field surveys. The average daily service time is settled at 16h
p_c	Charging station single distribution capacity, which is set at 3000 -4000 (kVA) in current paper
N_s	the number of fast charging stations
N_f	the number of normal charging stations
μ_s	Routine maintenance
μ_f	Special event standby coefficients
v_s	The proportion of ordinary charging methods for Class B users
v_f	The proportion of fast charging methods for Class B users
P_s	Charging powers of ordinary charging station
P_f	Charging powers of fast charging station
$T_{f,av}$	Required time for the fast method
$T_{s,av}$	Required time for the normal method
Z_1	City charging station fitness value
Z_2	Suburban charging station fitness value
Z_3	Rural charging station fitness value
N_Urbn	city population number
N_Subu	Suburban population
N_Rubrl	The number of rural population
$cost(i)$	the value function on Location x, Location y of the charging station

5 Models

5.1 Model for Total Demand of Electric Vehicles to Terminals

5.1.1 Calculation of Electric Vehicle Charging Demand

The common charging stations studied in this paper mainly provide services for electric taxis and other vehicles. A represents the vehicles need to be rapidly charged, A represents electric taxi, and A2 represents some other cars and B represents other cars that are charged using the conventional method. Among them, total power distribution of public charging stations includes two parts: (1) meet the charging needs of vehicles entering the station, (2) meet their own operational needs. Here to calculate the total charge of vehicle charging demand shape.

$$W_A = W_{A1} + W_{A2}$$

$$W_{A1} = W_{AV1} \times B_{K1} = W_{A1} \times N_0 \times B_{A1} \times a_p$$

$$W_{A2} = W_{AV2} \times B_{K2} = W_{AV2} \times N_P \times B_{A2} \times \gamma_1 \times a_p$$

As other cars are more concentrated in various commercial circles, stations, residential areas and other public places, the space forecasting method can be used to predict daily charge demand of the user -. Electric vehicle users show a regional distribution, different types of land, and different user charging needs. Therefore, when calculating the daily charging amount of an electric vehicle, it can be predicted according to the land properties of the area. Assuming that a test area is divided into N small areas, the daily charge of other cars in the area is:

$$W_B = \sum_{i=1}^{N} W_{Bi} \times N_{Bi} \times t_{Bi} \times a_p$$

Therefore, the distribution capacity of charging station vehicle are needed.

$$W = (W_{AV1} \times B_{K1} + W_{AV2} \times B_{K2}) + \sum_{i=1}^{N} W_{Bi} \times N_{BI} \times t_{Bi} \times a_p$$

According to the sub-formula, the value of distribution in the charging station vehicle is calculated. Then the number of charging stations was further calculated in accordance with the charging station construction standards.

5.1.2 Electric Vehicle Charging Station to Determine the Number of Needs

$$N_c = \frac{\varepsilon W}{p_c t}$$

$$W = (W_{AV1} \times B_{K1} + W_{AV2} \times B_{K2}) + \sum_{i=1}^{N} W_{Bi} \times N_{BI} \times t_{Bi} \times a_p$$

Different demand of users lead to different charging station configuration and charging method. The common ways of charging electric vehicles are constant current method and constant voltage method. Due to various demands of different types of users on the charging time, the charging station is divided into fast charging station and ordinary charging station. Among them, the fast charging station mainly targets Class C users while taking into account some of Class B users. The ordinary charging stations mainly target Class A users and some Class B users. Thus, the number of fast charging stations N_f and the number of normal charging stations N_s can be calculated.

$$N_s = \mu_s \frac{W_A + v_s W_B}{P_s T_{s,av}}$$

$$N_f = \mu_f \frac{W_C + v_f W_B}{P_f T_{f,av}}$$

Into the relevant data obtained after: the United States need **773824** charging stations.

The capacity and number of charging stations are inseparable. In the specific planning area, it is often necessary to consider the influence of many factors, such as transportation, land and power grid planning. If you choose a large capacity, it will affect the work of the transformer; if the number of charging station is too many, it will also result in waste of resources. planning form for the proposed charging station should be discussed by experts with several times to determine the final number of charging stations.

The distributions are shown in the following table displayed on Page 8.

USA； Urban； number:140（each point represented 770'000/200）								
x:00 y:02	x:00 y:34	x:00 y:36	x:01 y:14	x:01 y:17	x:01 y:26	x:01 y:31	x:02 y:10	x:02 y:35
x:02 y:45	x:02 y:48	x:03 y:20	x:03 y:46	x:03 y:49	x:04 y:17	x:04 y:36	x:04 y:46	x:05 y:26
x:05 y:41	x:05 y:46	x:06 y:07	x:06 y:13	x:06 y:14	x:06 y:24	x:06 y:38	x:06 y:49	x:07 y:30
x:08 y:00	x:08 y:45	x:10 y:28	x:10 y:34	x:11 y:20	x:11 y:20	x:11 y:23	x:13 y:15	x:14 y:11
x:14 y:11	x:14 y:22	x:14 y:38	x:15 y:07	x:16 y:06	x:16 y:24	x:16 y:36	x:17 y:30	x:18 y:48
x:19 y:09	x:19 y:14	x:19 y:20	x:20 y:04	x:20 y:20	x:20 y:38	x:20 y:45	x:21 y:00	x:21 y:01
x:21 y:02	x:21 y:25	x:22 y:00	x:22 y:06	x:22 y:24	x:22 y:27	x:22 y:30	x:22 y:32	x:22 y:36
x:22 y:40	x:22 y:43	x:23 y:19	x:23 y:24	x:23 y:38	x:23 y:46	x:24 y:24	x:25 y:20	x:25 y:35
x:25 y:40	x:25 y:49	x:26 y:33	x:27 y:10	x:28 y:07	x:28 y:24	x:28 y:47	x:29 y:18	x:30 y:03
x:30 y:13	x:30 y:40	x:30 y:48	x:31 y:45	x:32 y:11	x:32 y:19	x:32 y:39	x:32 y:42	x:32 y:44
x:32 y:46	x:33 y:18	x:33 y:22	x:33 y:27	x:33 y:29	x:33 y:30	x:34 y:03	x:35 y:49	x:36 y:14
x:36 y:17	x:36 y:33	x:36 y:35	x:37 y:02	x:38 y:07	x:38 y:31	x:38 y:32	x:38 y:32	x:39 y:05
x:39 y:12	x:39 y:21	x:39 y:39	x:40 y:15	x:41 y:12	x:41 y:29	x:41 y:33	x:42 y:12	x:42 y:33
x:43 y:02	x:43 y:22	x:45 y:06	x:45 y:11	x:45 y:26	x:45 y:32	x:45 y:38	x:46 y:01	x:46 y:34
x:47 y:00	x:47 y:00	x:47 y:06	x:47 y:14	x:47 y:24	x:48 y:02	x:48 y:04	x:48 y:07	x:48 y:27
x:48 y:28	x:48 y:36	x:48 y:38	x:28 y:16					

Fig 1: USA Urban

USA； Urban； number:140（each point represented 770'000/200）								
x:00 y:02	x:00 y:34	x:00 y:36	x:01 y:14	x:01 y:17	x:01 y:26	x:01 y:31	x:02 y:10	x:02 y:35
x:02 y:45	x:02 y:48	x:03 y:20	x:03 y:46	x:03 y:49	x:04 y:17	x:04 y:36	x:04 y:46	x:05 y:26
x:05 y:41	x:05 y:46	x:06 y:07	x:06 y:13	x:06 y:14	x:06 y:24	x:06 y:38	x:06 y:49	x:07 y:30
x:08 y:00	x:08 y:45	x:10 y:28	x:10 y:34	x:11 y:20	x:11 y:20	x:11 y:23	x:13 y:15	x:14 y:11
x:14 y:11	x:14 y:22	x:14 y:38	x:15 y:07	x:16 y:06	x:16 y:24	x:16 y:36	x:17 y:30	x:18 y:48
x:19 y:09	x:19 y:14	x:19 y:20	x:20 y:04	x:20 y:20	x:20 y:38	x:20 y:45	x:21 y:00	x:21 y:01
x:21 y:02	x:21 y:25	x:22 y:00	x:22 y:06	x:22 y:24	x:22 y:27	x:22 y:30	x:22 y:32	x:22 y:36
x:22 y:40	x:22 y:43	x:23 y:19	x:23 y:24	x:23 y:38	x:23 y:46	x:24 y:24	x:25 y:20	x:25 y:35
x:25 y:40	x:25 y:49	x:26 y:33	x:27 y:10	x:28 y:07	x:28 y:24	x:28 y:47	x:29 y:18	x:30 y:03
x:30 y:13	x:30 y:40	x:30 y:48	x:31 y:45	x:32 y:11	x:32 y:19	x:32 y:39	x:32 y:42	x:32 y:44
x:32 y:46	x:33 y:18	x:33 y:22	x:33 y:27	x:33 y:29	x:33 y:30	x:34 y:03	x:35 y:49	x:36 y:14
x:36 y:17	x:36 y:33	x:36 y:35	x:37 y:02	x:38 y:07	x:38 y:31	x:38 y:32	x:38 y:32	x:39 y:05
x:39 y:12	x:39 y:21	x:39 y:39	x:40 y:15	x:41 y:12	x:41 y:29	x:41 y:33	x:42 y:12	x:42 y:33
x:43 y:02	x:43 y:22	x:45 y:06	x:45 y:11	x:45 y:26	x:45 y:32	x:45 y:38	x:46 y:01	x:46 y:34
x:47 y:00	x:47 y:00	x:47 y:06	x:47 y:14	x:47 y:24	x:48 y:02	x:48 y:04	x:48 y:07	x:48 y:27
x:48 y:28	x:48 y:36	x:48 y:38	x:28 y:16					

Fig 2: USA Suburbs.png

USA； Rural Area； number: 20（each point represented 770’000/200）								
x:00 y:04	x:07 y:34	x:09 y:41	x:09 y:45	x:11 y:07	x:12 y:15	x:17 y:40	x:18 y:24	x:23 y:13
x:23 y:19	x:23 y:47	x:31 y:28	x:35 y:37	x:38 y:08	x:41 y:21	x:43 y:02	x:44 y:30	x:47 y:30
x:04 y:23	x:43 y:19							

Fig 3: USA Rural

5.2 Site Selection

5.2.1 Genetic Algorithm Model

Charging area are divided into three categories: city, suburban, and rural areas. The number of electric cars are designed according to the weights of cities, suburbs and rural areas. Considering the difference of population density, income level and consumption pattern in cities, suburbs and rural areas, we can solve them separately. According to greedy algorithm, we can see that:

$$Z_{\max} = Z_1 + Z_2 + Z_3$$

$$Z_1 = \sum_{i=1}^{N\_Urbn} cost\,(i)$$

$$Z_2 = \sum_{i=1}^{N\_Subu} cost\,(i)$$

$$Z_3 = \sum_{i=1}^{N\_Rubrl} cost\,(i)$$

The objective function is Z; Restrictions:

$$\begin{cases} 0 \le location_x \le num_c & location_x \in D \\ 0 \le location_y \le num_c & location_y \in D \end{cases}$$

Fitness function is also called evaluation function, this model uses the objective function as the fitness function. Cross process Prior to cross-reorganization according to individual fitness to re-sort individuals will be poor fitness eliminated, copy the good individuals to the eliminated individual position, through the random function to select the intersection, cross the intersection of chromosome position information before and after the coordinate Change, after the intersection of chromosome retention;

Variation process In this model, a single point mutation is adopted, the mutation point is selected by a random function, the position of the mutation point is randomly generated, and the fitness value of the individual is recalculated;

Termination principle There are three principles of termination of genetic algorithms:

- Stopping the iteration if the optimal solution is obtained within the maximum number of iterations selected in advance;
- Stop the iteration if the maximum number of iterations is reached;
- The model uses the second principle of termination.

Ireland；Urban；number: 70（each point represented 770’000/100）								
x:00 y:05	x:01 y:19	x:02 y:35	x:04 y:46	x:05 y:29	x:06 y:47	x:07 y:31	x:08 y:10	x:10 y:28
x:11 y:20	x:13 y:15	x:14 y:38	x:16 y:24	x:18 y:48	x:19 y:14	x:20 y:6	x:20 y:30	x:21 y:02
x:21 y:25	x:22 y:06	x:22 y:36	x:22 y:43	x:23 y:46	x:25 y:20	x:25 y:35	x:27 y:12	x:28 y:24
x:30 y:40	x:32 y:19	x:32 y:44	x:33 y:29	x:36 y:14	x:36 y:33	x:36 y:37	x:37 y:02	x:38 y:07
x:38 y:32	x:38 y:32	x:39 y:05	x:39 y:17	x:39 y:39	x:40 y:15	x:41 y:15	x:41 y:36	x:43 y:03
x:43 y:22	x:45 y:06	x:45 y:11	x:45 y:26	x:45 y:30	x:45 y:41	x:46 y:01	x:46 y:37	x:47 y:00
x:47 y:00	x:47 y:09	x:47 y:13	x:47 y:28	x:48 y:02	x:48 y:05	x:48 y:09	x:48 y:24	x:48 y:29
x:48 y:34	x:48 y:36	x:29 y:14						

Fig 4: Ireland Urban

Ireland；Urban；number: 70（each point represented 770’000/100）								
x:00 y:05	x:01 y:19	x:02 y:35	x:04 y:46	x:05 y:29	x:06 y:47	x:07 y:31	x:08 y:10	x:10 y:28
x:11 y:20	x:13 y:15	x:14 y:38	x:16 y:24	x:18 y:48	x:19 y:14	x:20 y:6	x:20 y:30	x:21 y:02
x:21 y:25	x:22 y:06	x:22 y:36	x:22 y:43	x:23 y:46	x:25 y:20	x:25 y:35	x:27 y:12	x:28 y:24
x:30 y:40	x:32 y:19	x:32 y:44	x:33 y:29	x:36 y:14	x:36 y:33	x:36 y:37	x:37 y:02	x:38 y:07
x:38 y:32	x:38 y:32	x:39 y:05	x:39 y:17	x:39 y:39	x:40 y:15	x:41 y:15	x:41 y:36	x:43 y:03
x:43 y:22	x:45 y:06	x:45 y:11	x:45 y:26	x:45 y:30	x:45 y:41	x:46 y:01	x:46 y:37	x:47 y:00
x:47 y:00	x:47 y:09	x:47 y:13	x:47 y:28	x:48 y:02	x:48 y:05	x:48 y:09	x:48 y:24	x:48 y:29
x:48 y:34	x:48 y:36	x:29 y:14						

Fig 5: Ireland Suburbs.png

Ireland；Rural Area；number: 10（each point represented 770’000/200）								
x:00 y:06	x:06 y:35	x:09 y:45	x:13 y:17	x:18 y:26	x:22 y:43	x:36 y:37	x:45 y:28	x:04 y:20
x:43 y:19								

Fig 6: Ireland Rural

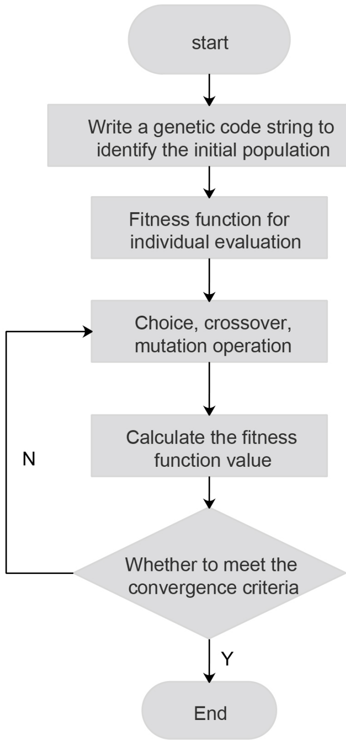

Fig 7: Genetic Algorithm Model

Considering the charging convenience and electric car mileage users are supported to give priority to choose the nearest charging station. When designing the the distribution of charging station, genetic algorithm model are employed above.

5.3 Logistic Growth Model Based on Limited Growth

The iteration of fuel-powered cars and electric cars can be analog to population growth. We consider the scaling factor k that measures the growth rate of electric vehicles as a function of the number of electric vehicles. As the electric vehicles grow and close to the maximum value M (the number of fuel trucks) The ratio k decreases gradually, and a simple case for k is a linear submodel.

$$k = r(M - P) \quad r > 0$$

$$\frac{dP}{dt} = r(M - P)P$$

Where r is a constant, predicting the number of electric vehicles P at a certain time $t = t_i$ in the future, we set the event condition $P(t_0) = P_0$ and deal with it

$$P(t) = \frac{MP_0}{[P_0 + (M - P_0)e^{-rM(t-t_0)}]}$$

There is only one unknowns in r, which can be obtained by observing the data of the past five years r=0.00115

Reference to the Irish population and the number of 2017 fuel trucks, estimated M=2400000 This shows that when the number of electric vehicles P reaches half of the limit amount M, the growth rate $\frac{dP}{dt}$ is the largest and then decreases to 0.

Into the data in previous years can be obtained:

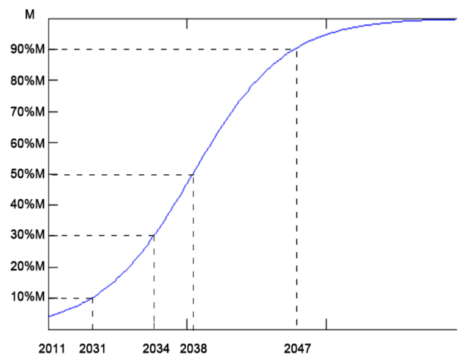

Fig 8: Logistic Carve

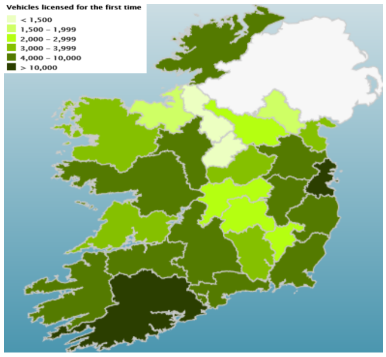

Fig 9: Population of Ireland

- When t=2031 P is 10% of M
- When t=2034 P is 30% of M
- When t=2038 P is 50% of M
- When t=2047 P is 90% of M

From the Logistic Curve, we can see that the development of electric vehicles is relatively slow in the early period, but the number of electric vehicles reaches the maximum at the rate of 50% M. Therefore, the government should introduce policies to stimulate the development of electric vehicles in the early stage and reduce the time to 50% M.

Taking small data model as an example, multi-objective optimization is addressed.

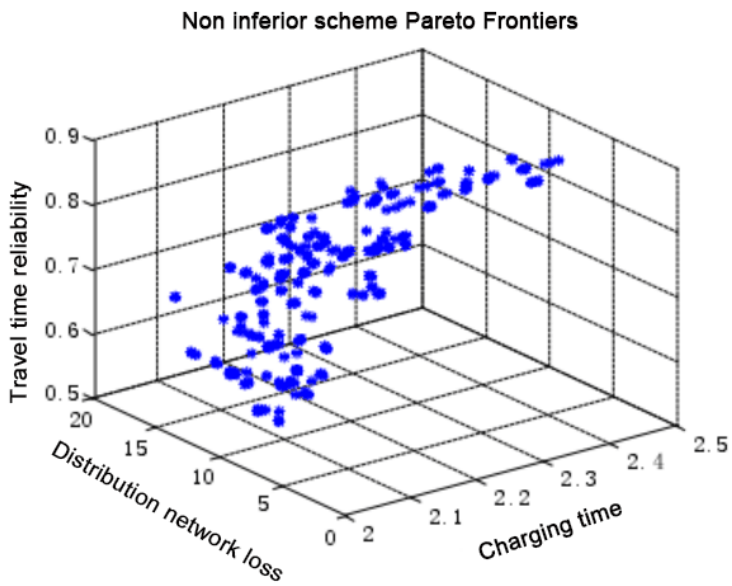

Fig 10: Small Data Model

5.4 Establishing Evaluation Model of Charging Station Network Based on the entropy weight method

5.4.1 Principle of the Entropy Weight Method

Entropy weight method is an objective weighting method that determines the weight of each evaluation index according to the amount of information of each evaluation index value. If the entropy value of an evaluation index is smaller, its weight is also larger. In this study, real sample data is used for comprehensive evaluation, and entropy weight method can be used to obtain a more objective and accurate indicator weight.

5.4.2 Entropy Weight Method Calculation Steps

Step 1 Construct Evaluation Index Matrix

Five countries as the evaluation object, evaluation index 12, the establishment of evaluation index data matrix X, where X_{ij} means the i country j evaluation

$$X = \begin{pmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} \\ \dots & \dots & \dots & \dots & \dots \\ x_{121} & x_{122} & x_{123} & x_{124} & x_{125} \end{pmatrix}$$

Step 2 Index Data Standardization

As the indicators do not have a unified unit of measurement, we need to standardize and eliminate the impact of the polarity of the units and indicators before the assessment

- The positive standardization formula

$$x_{ij}^* = \frac{x_{ij} - \min\limits_{0\le j\le 5}(x_{ij})}{\max\limits_{0\le j\le 5}(x_{ij}) - \min\limits_{0\le j\le 5}(x_{ij})}$$

- The inverse standardization formula

$$x_{ij}^* = \frac{\max\limits_{0\le j\le 5}(x_{ij}) - x_{ij}}{\max\limits_{0\le j\le 5}(x_{ij}) - \min\limits_{0\le j\le 5}(x_{ij})}$$

- The standardization of appropriate indicators

$$x_{ij} = 1 - \frac{|x_{ij} - x_i^*|}{\max|x_i - x_i^*|}$$

The matrix X is processed according to a standardized formula to obtain a normalized matrix X^*

$$X^* = (x_{ij}^*)_{12\times 5} = \begin{pmatrix} x_{11}^* & x_{12}^* & x_{13}^* & x_{14}^* & x_{15}^* \\ x_{21}^* & x_{22}^* & x_{23}^* & x_{24}^* & x_{25}^* \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{121}^* & x_{122}^* & x_{123}^* & x_{124}^* & x_{125}^* \end{pmatrix}$$

Step 3 Indicator Data Normalized
Normalized formula

$$f_{ij} = x_{ij}^* \Big/ \sum_{j=1}^{5} x_{ij}^*$$

The matrix X^* is normalized to obtain a normalized matrix F

$$F = \begin{pmatrix} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} \\ f_{21} & f_{22} & f_{23} & f_{24} & f_{25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ f_{121} & f_{122} & f_{123} & f_{124} & f_{1215} \end{pmatrix}$$

Step 4 Seek the Entropy of each Index

$$H_i = -K \sum_{j=1}^{5} f_{ij} \ln f_{ij}$$

Where H_i is the entropy of the f_ij , indicator: f_ij ln f_ij = 0 when f_ij = 0
Step 5 Determine the Entropy of each Index

$$w_i = (1 - H_i) \Big/ (n - \sum_{i=1}^{12} H_i)$$

We can get the entropy weight vector of 12 evaluation indexes:

$$W = (w_1, w_2, w_3, \cdots, w_n)^T$$

Symbol	Meaning
B_1	GDP
B_2	Population density
B_3	Electricity fee
B_4	Oil prices
B_5	Replace battery costs
B_6	National policy subsidies
B_7	Impact on the distribution network
B_8	Electric vehicle prices
B_9	Full range of electric mileage
B_{10}	Charging frequency
B_{11}	The number of charging stations
B_{12}	Charge station costs

Bringing into the equation, we can get the weight vector of network development of charging station

$$W = (0.1668, 0.1023, 0.0544, 0.1172, 0.0896, 0.0505,$$
$$0.0507, 0.0421, 0.0653, 0.0662, 0.0513, 0.0407, 0.0488)^T$$

Top 5 factors: B6, B8, B5, B10, B12

6 Strengths and Weakness

6.1 Strengths

- With strong universality and robustness, this model combines both algorithm and genetic. in the case of a large number of data support, the degree of function can be further optimized and more accurate.
- Entropy method can be applied to the determination of the weight of the indicators in most of the evaluation problems, and to reduce the evaluation index which has less influence on the evaluation in the index system.
- The demand model divided drivers into A, B car owners, private cars and taxis, so we can more accurately determine the number of charging stations.
- The demand model used to calculate the number of charging stations applies to all countries.
- Logistic model more in line with the actual situation.

- Different countries can get the key factors affecting the development of their charging station network through the comprehensive evaluation model.

6.2 Weaknesses

- **We are short of the data.** Logistic curve requires a large amount of data to be fully fitted, but electric vehicles are emerging fields with few data, and the fitted prediction values are less in line with the actual situation.
- **Our consideration is so limited.** We did not consider the three-dimensional multi-function charging station. Three-dimensional charging station: Building-based, high space utilization, can be applied to the construction area of tension and heavy trucks, buses. Depending on the area and cost of construction, there are three types of charging stations to choose from self-contained three-dimensional charging station, lifting the vertical three-dimensional charging station and vertical lift charging station.
- In the process of meshing, if the mesh is too dense, the model will easily fall into the local optimal solution. If the mesh is too rough, close to the number of charging stations, it is easy to cause an average distribution, while ignoring the other factors affecting the division of the region.

7 Growth Analysis

With the rapid establishment of rapid battery-swap stations and enough charging stations and the development of four major electric vehicles, the standard voltage problem will also be improved. Although there are four flaws, but as long as the charging technology, battery capacity density as long as there is a major breakthrough in both, you can solve the problem of battery life and battery replacement costs. In addition, if the autopilot technology is extremely mature, the cost of the taxi will become extremely low, which may serve as the main mode of travel for the future cities so that people no longer need a long electric car mileage. The flying car, which is known as the key to a traffic jam free world, has greatly relieved traffic pressure. Therefore, improvements in power train systems and establishment of air traffic control systems are also urgently needed. The development of nuclear power and other technologies may further reduce the cost of electricity in the future. However, in this process, the problem of battery pollution should also be solved to seek a more environmentally friendly, longer-lived and larger battery.

Boston Consulting Group (BCG) research on automotive innovation shows that the emergence of shared self-driving electric vehicles will usher in the most radical changes in urban life in the United States, many factors indicate that this change is imminent, thus stimulating the development of electric vehicles. The study notes that as many as 175 million Americans living in the largest cities in the United States by 2030 will be heading for shared self-driving electric vehicles, which are expected to account for 25% of all car miles in the United States, cutting nearly 50% of the cost of transportation to make more efficient use of time; the cost of personal mobile travel has dropped sharply by 50% (Fig 11 shows below); personal disposable income almost doubled and the new purchasing power of a huge new economic impact.

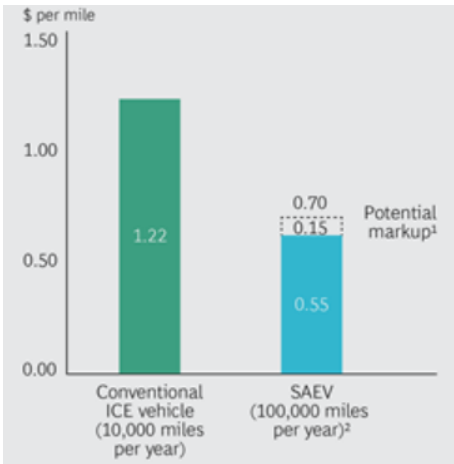

Fig11: Personal Travel Costs

As the development of electric vehicles approaches saturation, the development of Hyperloop has provided people with a faster way to travel and has significantly reduced personal expenses compared to owning an electric vehicle, thus contributing to the development of electric vehicles Certain negative feedback effect.According to the above analysis can be drawn, the development trend of electric vehicles generally appear as Logistic Curve.

8 Handout

Ladies and Gentlemen.

In recent years, the green development is booming in the world. Due to economic and environmental reasons, the development of new energy vehicles is the trend of the times.The future of automotive development, is bound to be an intelligent, pure electric-driven development. However, migrating personal transportation towards all-electric cars must be a thorny process. The key factors affecting this process include the following:

First, the national policy, subsidy support.The initial growth of electric vehicles is bound to slow growth, national subsidy policy is imperative in order to stimulate the rapid development of electric vehicles . Support the policy of convergence should be sufficient to prohibit the existence of local protectionism, to avoid causing market fragmentation, inhibit the vitality of development and actively adjust the economic structure and increase energy-saving emission reduction strength.

Second, Charging network planning and cost.Good charging infrastructure and reasonable facilities layout so as to form a sustainable business development mode. Charging station settings should meet the overall urban planning and road network planning requirements, but also consider the population density, wealth distribution and other factors to improve energy efficiency. Should also take full account of the status of the region's transmission and distribution grids, the need for high-power power supply support, and higher supply voltage to meet the faster charging speed.

Third, the battery life and replacement costs. Electric vehicle's battery is called its "heart", subject to the battery cost, weight, life expectancy and battery management technology, electric vehicles generally low mileage. The next 15 years, pure electric if you can not improve the mileage,the development will be difficult, technological breakthroughs is imperative.

Other factors such as GDP, electricity bills, oil prices and other factors will also affect the development of all-electric development. "Monofilament is not a line, single wood is not a forest," to strengthen international cooperation promote sustainable innovation, committed to the development of future energy and the automotive industry is healthy, fast and sustainable, building a new world of green and sustainable development!

Thank you!
#83183

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Appendices and Supporting Data

Genetic Algorithm Model

```
#include<iostream>
#include "cstdio"
#include "cstdlib"
#include "conio.h"
#include "cmath"
#include "ctime"
#include<cstdlib>
#include<algorithm>
using namespace std;
#define num_C 50   //
#define N_Urbn    int(Total_EC*weight_Urbn) //          ,
#define N_Subu    int(Total_EC*weight_Subu) //             ,
#define N_Rubrl   int(Total_EC*weight_Rurl) //
#define pc      0.9  //     ł0     .9
#define pm      0.1  //     ł0     .1
#define ps      0.6  //
#define genmax 200 //    200
#define weight_Urbn 0.7//
#define weight_Subu 0.2//
#define weight_Rurl 0.1//
#define Total_EC   200    //
#define Type_Urbn 1     //     ł1
#define Type_Subn 2     //     ł2
#define Type_Rubrl 3    //     ł3
struct Location
{
  int location_x;
  int location_y; //
  int cost;        //                        ł
};
struct Location group_Urbn[N_Urbn]; //
struct Location group_Subn[N_Subu]; //
struct Location group_Rurl[N_Rubrl]; //
int num_gen=0;        //

int RandomInteger(int low,int high);//
void Initial_gen(int type);//
void Sort(int type);//
void Copy_unit(struct Location *p1,struct Location *p2);//
void Cross(int type);//
void Varation(int i,int type);//
void Evolution(int type);//
int Calculate_cost(struct Location *p);//
int Calculate_cost_sum(int type);//
```

```
void Print_optimum(int k,int type);//
int comp(Location a,Location b);
int main()
{
  srand((int)time(NULL)); //
   Initial_gen (Type_Urbn);
   Initial_gen (Type_Subn);
   Initial_gen (Type_Rubrl);
  Evolution(Type_Urbn);
  Evolution(Type_Subn);
  Evolution(Type_Rubrl);//
  Print_optimum(Type_Urbn,Type_Urbn);
  Print_optimum(Type_Subn,Type_Subn);
  Print_optimum(Type_Rubrl,Type_Rubrl);
  getch();
  return 0;
}
/*              */
void Initial_gen (int type)
{
  int i,j,x,y,num;
  struct Location *p,*temp1,*temp2;
  if(type==1)
    {
        p=group_Urbn;
        num=N_Urbn;
    }
  else if(type==2)
   {
      p=group_Subn;
      num=N_Subu;
   }
  else
    {
        p=group_Rurl;
        num=N_Rubrl;
    }
  temp1=p;
  for(i=0;i<=num-1;i++) //
        {
        //          pi
        x=RandomInteger(0,num_C-1);
        y=RandomInteger(0,num_C-1);
        temp1->location_x=x;
        temp1->location_y=y;
        if(i>0)
        {
           for(j=0;j<=i-1;j++)
           {
```

```
                temp2=p;
                if ((temp2->location_x==temp1->location_x)&&(temp2->location_y==temp1->location_y))
                {
                    x=RandomInteger(0,num_C-1);
                    y=RandomInteger(0,num_C-1);
                    temp1->location_x=x;
                    temp1->location_y=y;
                    j=0;
                    break;
                }
            }
        }
    temp1->cost=8;
    if (x==0||x==num_C-1);
    temp1->cost-=3;
    if (y==0||y==num_C-1)
    temp1->cost-=3;
    if ((x==0&&y==0)||(x==0&&y==num_C-1)||(x==num_C-1&&y==0)||(x==num_C-1&&y==num_C-1))
        temp1->cost++;
      temp1++;
    }
              Calculate_cost(p);
}
/*              genmax              */
void Evolution(int type)
{
    int i,j,num;
    int temp1,temp2,temp3,temp4,temp5;
    struct Location *p;
    if (type==1)
    {
        p=group_Urbn;
        num=N_Urbn;
    }
    else if (type==2)
     {
        p=group_Subn;
        num=N_Subu;
     }
    else
    {
          p=group_Rurl;
          num=N_Rubrl;
    }
    temp1=num*pc/2;//    pcł0   .9 100 *0.45 45
    temp2=num*(1-pc);//100*0.110
    temp3=num*(1-pc/2);//100*0.5555
    temp4=num*(1-ps); //           ps
    temp5=num*ps;
```

```
    for(i=1;i<=genmax;i++)
    {
       Sort(type);
           //Print_optimum(group,i−1); //      ( i  −1  )
       for(j=0;j<=temp4−1;j++)
           {
              Copy_unit((p+j),(p+j+temp5));
       }//                                        sortgrouptemp4łłł
            //
          Cross(type);
      Varation(i,type);
     }
     Sort(type);
     sort(p,p+num,comp);
  }
  /*       */
  void Cross(int type)//            ł
  {
    int i,j,cross_point,num;
    struct Location son[num_C],*p,*temp,*temp2;
    if(type==1)
    {
       p=group_Urbn;
       num=N_Urbn;
    }
    else if(type==2)
    {
      p=group_Subn;
      num=N_Subu;
    }
    else
    {
       p=group_Rurl;
       num=N_Rubrl;
    }
    temp=p;
    temp2=p+1;
    for(i=0;i<=num_C−1;i++) //  son1son2
    {
           son[i].location_x=−1;//int k
           son[i].location_y=−1;
           son[i].cost=−1;
    }
    cross_point=RandomInteger(1,num_C−1); //
    for(i=0;i<=cross_point−1;i++)
    {
       son[i].location_x=p[i].location_y;
       son[i].location_y=p[i].location_x;
       son[i].cost=Calculate_cost(&son[i]);
```

```
    }
    for(i=cross_point;i<=num_C-1;i++)
    {
        son[i].location_x=p[i].location_x;
        son[i].location_y=p[i].location_y;
        son[i].cost=p[i].cost;
    }
    for(i=0;i<=num_C-1;i++)
    {
        p->location_x=son[i].location_x;
        p->location_y=son[i].location_y;
        p->cost=son[i].cost;
    }
    for(i=0;i<=num-1;i++) //
    {
      //            pi
      if(i>0)
      {
          for(j=0;j<=i-1;j++)
          {
              if((temp2->location_x==temp->location_x)&&(temp2->location_y==temp->location_y))
              {
                  temp->location_x=RandomInteger(0,num_C-1);
                  temp->location_y=RandomInteger(0,num_C-1);
                  j=0;
                  break;
               }
               temp2++;
          }
      }
         temp++;
     }
    Calculate_cost_sum(type);
  }/*       */
void Varation(int flag_v,int type)
{
    int flag,i,j,num;
    struct Location *p,*temp;
    flag=RandomInteger(1,100);
    if(type==1)
    {
        p=group_Urbn;
        num=N_Urbn;
    }
    else if(type==2)
    {
      p=group_Subn;
      num=N_Subu;
    }
```

```
    else
    {
        p=group_Rurl;
        num=N_Rubrl;
    }
    //
    if(flag<=(flag_v>100)?(5*100*pm):(100*pm)) //   ł10   %
     {
            i=RandomInteger(0,num-1);  //
            p->location_x=RandomInteger(0,num_C-1);
        p->location_y=RandomInteger(0,num_C-1);
        for(j=0;j<=num_C-1;j++)
        {
            if(i!=j)
            {
              temp=p+j;
              if((temp->location_x==p->location_x)&&(temp->location_y==p->location_y))
              {
                  p->location_x=RandomInteger(0,num_C-1);
                  p->location_y=RandomInteger(0,num_C-1);
                  p->cost=Calculate_cost(p);
                  j=0;
                  break;
               }
        }
            Calculate_cost_sum(type);              //
        }
     }
  }
  void Sort(int type)
  {
    int i,j,num;
    struct Location temp,*p,*p1,*p2;
    if(type==1)
    {
      p=group_Urbn;
      num=N_Urbn;
    }
    else if(type==2)
    {
      p=group_Subn;
      num=N_Subu;
    }
    else
    {
      p=group_Rurl;
      num=N_Rubrl;
   }
    for(j=1;j<=num-1;j++) //      N      -1
```

```
    {
            for(i=1;i<=num-1;i++)
        {
                p1=p+i-1;
                    p2=p+i;
                    if(p1->cost>p2->cost) //
            {
                        Copy_unit(p1,&temp);
                Copy_unit(p2,p1);
                Copy_unit(&temp,p2);
            }
        }
    }
}
/*                    */
int Calculate_cost(struct Location *p)
{
  int x,y;
  p->cost=8;
  x=p->location_x;
  y=p->location_y;
  if(x==0||x==num_C-1);
     p->cost-=3;
  if(y==0||y==num_C-1)
    p->cost-=3;
  if((x==0&&y==0)||(x==0&&y==num_C-1)||(x==num_C-1&&y==0)||(x==num_C-1&&y==num_C-1))
    p->cost++;
 return p->cost;
}
int Calculate_cost_sum(int type)
{
    int i,sum=0,num;
    struct Location *p;
    if(type==1)
    {
       p=group_Urbn;
       num=N_Urbn;
    }
    else if(type==3)
    {
      p=group_Subn;
      num=N_Subu;
    }
    else
    {
      p=group_Rurl;
      num=N_Rubrl;
    }
    for(i=0;i<=num-1;i++)
```

```
    {
        sum=p->cost;
        p++;
    }
    return sum;
}
/*          p1p2          */
void Copy_unit(struct Location *p1,struct  Location *p2)//      p1p2
{
  int  i;
  for(i=0;i<=num_C-1;i++)
  {
     p2->location_x=p1->location_x;
     p2->location_y=p1->location_y;
     p2->cost=p1->cost;
  }
}
/*                                    */
int  RandomInteger(int low,int high)
{
  int  k;
  double d;
  k=rand();
  k=(k!=RAND_MAX)?k:(k-1); //        RAND_MAXVC
  d=(double)k/((double)(RAND_MAX));
  k=(int)(d*(high-low+1));
  return  (low+k);
}
/*                              */
void Print_optimum(int k,int type)
{
  int  i,j,num;
  struct  Location *p;
  if(type==1)
  {
     p=group_Urbn;
     num=N_Urbn;
     cout<<"          ł          "<<endl;
  }
  else  if(type==2)
  {
     p=group_Subn;
     num=N_Subu;
     cout<<"          ł          "<<endl;
  }
  else
  {
    p=group_Rurl;
    num=N_Rubrl;
```

```
        cout<<"           ł           :"<<endl;
    }
    for(i=0;i<=num-1;i++)
    {
        cout<<"x:"<<(p->location_x)<<"  y:"<<(p->location_y)<<endl;
            p++;
    }
}
int comp(Location a,Location b)//
{
    if(a.cost!=b.cost)
         return a.cost<b.cost;
     else  if(a.location_x!=b.location_x)
         return a.location_x<b.location_x;
     else
         return a.location_y<b.location_y;
}
```