Placement of Charging Station Based on User's Travel Habits

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Abstract

Under the pressure of energy and environmental protection, new energy vehicles will become the direction of the future cars. The issue of placing the charging stations scientifically is of great importance, because it's the basic guarantee of using electric vehicles. Given this background, a systematical approach base on user's travel habits and geographical zones is proposed. First, in order to simplify the driving route, we define the concept of travel chain which refers to the different forms of connection between what individual to complete one or several activities (multi-purpose travel) has visited to. Second, we divide a region into different functional areas based on the geographical environment and population. Then we get each travel habit's rate according to the previous survey. Last, we choose Ireland as our research object, and the placement of charging comes out, with the useless driving cost and comfort level as limitation factors, by Genetic Algorithm [1].

Keywords

Travel Habits, Charging Station, Placement, Electric Vehicle.

1. Introduction

Recently, it can be found that electric vehicle is coming into use gradually. There is no doubt that EV is the substitution of gasoline car and can replace it one day. And the construction of charging stations is of the most importance. A suitable site can not only serve the EVs more efficiently, but also can reduce the total cost of construction and operation. We read some paper about how to resolve the problem of sites of charging stations. There are some scholars consider it as a Maximum Covering Location Problem. Creatively, we come up with the idea that we can solve this problem with cost and comfort as restrictions based on EV user's travel habits and geography, combining with the Genetic Algorithm.

2. Model Assumption

2.1 Travel Chain Assumption.

Considering the different purpose of travel, we classify five kinds, H(Home), W(Work), SE(Shopping and Eating), SR(Social and Recreational), and O(Other family / personal errands), which are shown in Figure1.[2]

Home is both start and end of an individual's travel chain.

There is a difference of EV's need between weekdays and weekends.

The following three types of activities are mainly considered: a typical two-point and one-line type, as shown in Figure 1 (a); SR / SE / O activities on the way out of work, leaving home after the activity ends, as shown in Figure 1 (b) ; Go home after get off work, then proceed from home to carry out SR / SE / O activities, after the event, back home, and the journey shown in Figure 1 (a), (c) below.

On the weekends, EV users are mainly considered to be SR / SE / O activities starting from their homes and ending their journey back home which is shown in Figure 1 (c).

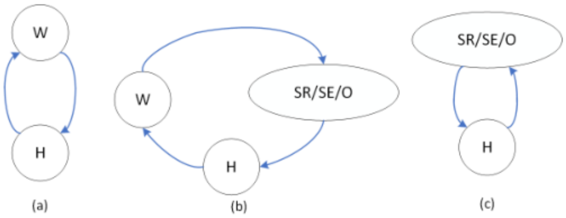

Figure 1: Typical structure of trip chain

2.2 Demand of Charging Assumption.

In fact, the location and ease of charging stations are crucial to early adopters and volunteers who eventually become mainstream consumers. Therefore, in order to make people have the best travel experience and improve the charging comfort, we choose to minimize the cost of going to charging station with the restriction of traffic flow.

• EV users choose their destination based on their individuals' travel needs.

• It is assumed that parking lots all have slow charger.

• We choose a typical area to simulate, assuming that EV can arrive at destination after once charging, regardless of long distance travel.

• EV users will choose to get charged at the charge station with the min driving cost and traffic flow.

3. Symbol Description

•L_{min} : the shortest distance of start and destination.

•$L^i_{S\text{-}D}$: ravel distance from destination directly to destination.

•$L^i_{S\text{-}C}$: the distance of start and charge station i.

•$L^i_{C\text{-}D}$: the distance of and charge station I and destination.

•SOC_L : EV's remaining battery.

•N^i_S : comfort of charging station i.

•T^i_{CS} : the overall cost of charging station i is minimized and the minimization of charging car flow.

Table 1 Three Scheme comparing

Numble	Scheme 1	Scheme 2	Scheme 3
1	456	456	123
2	789	213	644
3	213	654	649

4. The Model Construction

4.1 Travel Rate Calculation

A survey on workers in Boston 14 shows that 24.1% of them will go another place on the way home, and about 23.1% will have a travel after having arrived home. Therefore, we assume that the probabilities of the three main activities are 52.8 %, 24.1%, and 23.1%.

Each travel 's data structure can be described as follows:

$$CH= [\ SL,\ EL\ ,\ ST\ ] \tag{1}$$

Where SL denotes the source. El denotes the destination. ST denotes the start time.

In 2016, the U.S. Department of Transportation conducted statistics on the travel of the nationwide household vehicles. The statistical results show that the vehicles both meet the normal distribution at the first travel time and the last travel time. Therefore, we assume that during the weekday, EV users' first trips and off hours are subject to normal distribution.

μ_e is 6.92, σ_e is 1.24.

μ_s is 17.47, σ_s is 1.8.

During the rest day, the probability of the user going out is 70%, of which 35% travel time follows the normal distribution of $\mu_{e1} = 8.92$, $\sigma_{e1} = 3.24$ and 35% follows the normal distribution of $\mu_{e2} = 16.47$ and $\sigma_{e2} = 3.41$.

4.2 Charging Demand Analysis

We give out general formulas to calculate L_s below:

$$L_s = \frac{(SOC_L - SOC_{min})\, C_B}{E_a} \tag{2}$$

SOC_L is the remaining capacity of the battery before start, SOC_{min} is the lower limit of the battery, C_B is the capacity of the battery of EV, E_a is the average energy consumption per km of EV.

Analysis: EV users select the destination according to their travel needs, and calculate the shortest distance between the starting point and the destination, denoted as L_{min}. Assuming that each parking lot has slow charging piles, if $L_s > L_{min}$, the EV does not need to be charged, and can directly go to the destination according to the shortest planned route and then charge to the destination; otherwise, the EV needs to operate at the driving radius L_s choose a charging station for quick charging, and then to the destination.

Unloaded cost

The cost of useless driving refers to the distance that the EV travels for extra travel, so the objective function of minimizing the cost of air travel is given by equation 3.

$$\min_{i \in S_{CS}} \Delta L^i = L^i_{S-C} + L^i_{C-D} - L_{S-D} \tag{3}$$

The comfort of EVs

The degree of comfort of charging is mainly related to the traffic flow of the charging station. When there are too many traffic flows in the station, it is easy to cause congestion and queuing for a long time and reduce the comfort of EV charging. The objective function of minimizing traffic flow is as follows.

$$\min_{i \in S_{CS}} N^i_S = f^i_N(ST + t^i_A) \tag{4}$$

N^i_S is the degree of comfort of charging station i. $F^i_N(t)$ is the number of EV that reserve at the number i charging station at the time t. t^i_A is the time getting to the charging station i.

Comprehensive model

The objective function of minimizing the total cost of empty driving and minimizing the flow of the charging car is shown in Eq. (5)

$$\min_{i \in S_{CS}} T^i_{CS} = a\frac{\Delta L^i}{L^{\max}} + b\frac{N^i_S}{N^{\max}_S} \tag{5}$$

Where a and b is the weight coefficient, which is determined by users' preference. L_{max} is the max travel length. N_S^{max} is the max number of EVs that one charging station can serve.

5. Model Simulation

5.1 Overall distribution

According to the survey, there are five cities in Ireland including Dublin, Cork, Galway, Limerick and Waterford. The distribution of urban and suburban populations is as follows.[3]

Table 2 Site selection of charging station

City	Built time	City’s Population	Population
Dublin	1171	505,739	1,045,769
Cork	1185	119,418	190,384
Galway	1484	72,414	72,729
Limerick	1197	52,560	90,757
Waterford	1171	45,775	49,213

By looking up the literature, we get the distribution of the Irish population as follows:[4]

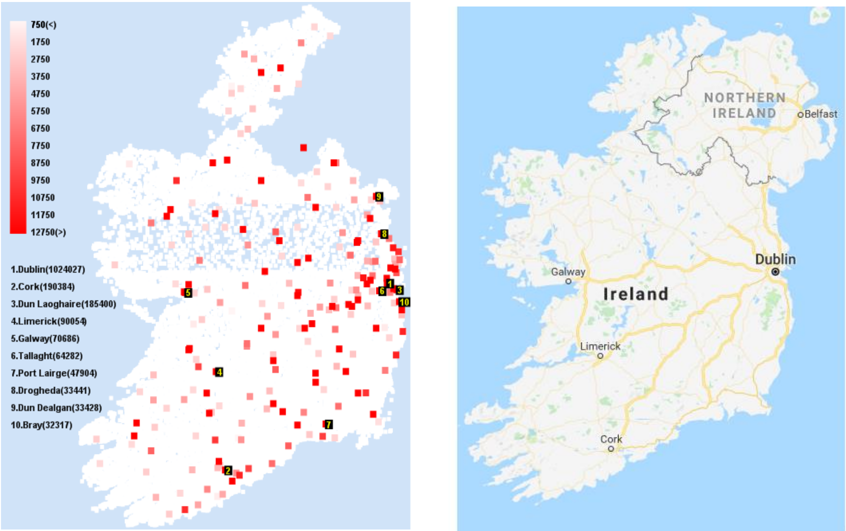

Figure 2: The distribution of the Irish population

The map lists the top ten regions of the population, some of which may not be urban, but we regard them as cities based on their population density. And in addition to the indicated area, the other area is suburban. For less populated, unlabeled areas, here we consider them rural and evenly distributed. According to the first question, we get Ireland's cities, suburbs and rural areas were 45%, 36%, 19%. Based on this ratio, we generate charging stations around the city, suburbs and countryside through random functions. Since there are millions of final builds, we've evaluated them here, and we get the pictures.

5.2 Example scenario

We simulated with actual background data in Ireland, and simulate the experimental road network by dividing the entire simulation area into residential, commercial and industrial areas. As shown in Fig. 3, The value in the middle of the line is the distance between two nodes on the road in km, and the site for constructing the rapid charging station is the intersection of the roads. It is assumed that charging piles have been built in the parking lots all over the country. The charging mode is slow charging. The EV can be charged while parking. The EV in the traveling time saves time and goes to the charging station when charging. The charging mode is fast charging.

Figure 3: map and simplify nodes

There are altogether 4,000 EVs in the simulation area. According to the technical parameters of tesla model3[5], the lithium battery capacity of EV is 24 kW · h, the power consumption of 100km travels E 100 = 15 kW · h, the cruising range is 160 km and the quick charging time is 15 min, the charging power is 96 kW and the average speed of EV is va = 40 km / h. Excessive charge and discharge will shorten the service life of the battery. Therefore, set the battery capacity lower limit SOC_{min} to 0.1 and the capacity upper limit SOC_{max} to is 0.9, EVL battery remaining capacity SOC_L to meet the [0.8, 0.9] of the uniform distribution, off to meet [0.5, 0.9] uniform distribution, $SOCmin_L = 0.5$; EV select charging station, a = 0.5, b = 0.5, $L_{max} = 160$,

$N_{maxS} = 15$; NmaxC = 15. (But also replace the specific value)

Among the various types of activities, H is located in a residential area; W is located in an industrial area or a commercial area, which occupies 80% of the industrial area; and the SR / SE / O is in a commercial area. EV users travel, according to the type of travel activities in different regions randomly selected destination. The duration of the SR / SE / O activity on the EV user working day satisfies the uniform distribution of [1, 2] h and the rest day satisfies the uniform distribution of [1, 5] h.

5.3 Site selection of charging station

Based on genetic algorithm, we get the optimal location scheme of fast charging station. Simulation results show that when there are only two charging stations, it can not be ensured that all EVs satisfy the constraint of Eq. (4). When seven charging stations are built, the objective function of Eq. (5) is 0, and all EVs The "way" charge. Therefore, the number of viable charging stations is 3 ~7. Different charging station construction site selection plan in Table 3.

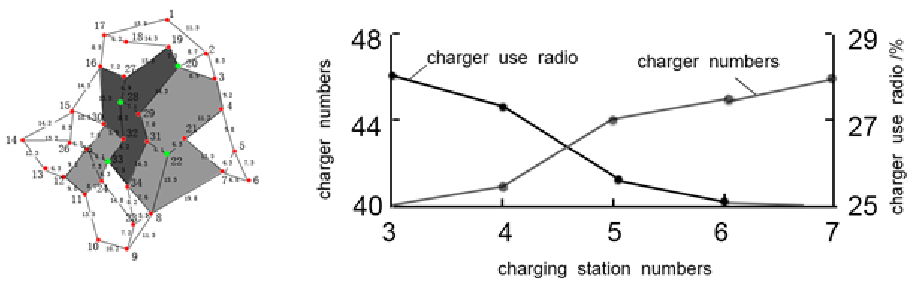

Figure 4: Position of charging station

Table 3 Site selection of charging station

Number of station	Optimal location	Useless cost
3	[3,8,20]	4001
4	[4,8,20,23]	2503
5	[4,8,12,20,23]	1027
6	[2,5,8,15,20,31]	361
7	[3,13,15,19,21,26,31]	0

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