Analysis on the Influencing Factors of Driving Mileage of Electric Vehicles: A Case Study of Taxis in Beijing

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Abstract. With the seriousness of energy and environment problem, the electric vehicle (EV) has been widely used. However, the low endurance mileage limits the popularization of electric vehicles (EVs). The aim of this work is to study the influencing factors of driving mileage and then take appropriate measures to extend it as possible. In this paper, the influencing factors of driving mileage are discussed based on the operation data of electric taxis monitored by the Electric Vehicles Monitoring and Service Center of Beijing (EVMSC). The results illustrate that the driving mileage is maximum when the ambient temperature is around 20°C, which will decrease with temperature rising or dropping. Furthermore, the aggressive driving behaviors will increase the consumption of energy and decrease the driving mileage. Lastly, the driving mileage increases with the increase of charging frequency and charging capacity. The conclusions of this work can give EV drivers of EVMSC driving instructions to help them reach the next charging station or the destination in safety and in time.

Introduction

Owing to the excellent performance in environmental friendliness and driving economy, EVs, including electric taxis and electric buses, are increasingly used in the field of public transport in Beijing. So far, over 2000 electric taxis have been used in more than 10 districts in Beijing area. However, the deficiency of endurance mileage and long recharging time prevent the popularity of electric taxi to a great extent. It is seen that endurance mileages of EVs are almost below 200km, which is constrained with the weight and energy density of battery. While for gasoline vehicles, a full tank could support a driving range of more than 600km. The lower EV endurance mileage is, the more anxious EV consumers will be, especially electric taxi drivers. To make full use of endurance mileage and reduce mileage anxiety of EV consumers, research on the influencing factors of driving mileage of EV is especially important and necessary. Besides, more efforts should also be made to extend driving mileage in the current technical background.

Lots of efforts have been contributed in the analysis of influencing factors of driving mileage of EVs. In previous work, several factors have been found influencing EV energy consumption, such as ambient temperature, route type, driving habits, traffic conditions, vehicle accessory utilization, and so on [1]. C. Bingham et al. focused on the impact of driving behaviors. According to the standard deviation (SD) of acceleration, the driving behavior was classified to three levels including aggressive, normal and calm. The relationship between driving behaviors and energy consumption was presented [2]. Wikstrom M et al. presented findings from a 3-year study of 550 EVs and their users in Sweden. They found that winter conditions seem to result in an unjustified decrease in use and a substantial share of battery capacity is redundant. It was found that this was not due to the technical constraints of the vehicles but in virtue of the drivers using the EVs in those conditions [3].
However, there is little work on electric taxis compared with private car, and the driving mileage and time of taxis are much longer. Owing to this, the taxi drivers’ demand and anxiety for driving mileage are higher than ordinary. Thus, this work focuses on electric taxis to find out the main influencing factors of driving mileage of electric taxis. The aim is to reduce EV drivers’ anxiety and adapt drivers’ driving habits to ensure the best conditions of EVs. To achieve this goal, we analyzed the operation data of electric taxis in Beijing area for one year to understand the energy consumption of EVs and investigated the major influencing factors of the driving mileage, which can be concluded as ambient temperature, driving patterns, charging behaviors, etc.

The remainder of this paper is organized as follows. Section 2 provides the operation analysis of electric taxis in Beijing based on the historical data collected from EVMSC in 2016. Section 3 analyzes the influencing factors of driving mileage of electric taxis. Section 4 presents the conclusion of this work.

**Operation Analysis of Electric Taxis**

**Big Data Platform**

In recent years, Beijing has been encouraging and supporting the public service industry, enterprises and individuals to use new energy vehicles (NEVs), and strives to build a green, low-carbon and environment-friendly urban environment. In the field of public service, Beijing municipal government has promoted using electric taxis, electric buses, electric trucks and rental battery electric vehicles (BEVs) as the demonstration application since 2009. In September 2009, 30 electric sanitation vehicles were put into trial operation. In January 2011, 50 electric taxis, and in June 1060 electric sanitation vehicles and 50 electric buses were put into demonstration operation. Due to the promotion of government, by the end of 2016, the number of electric taxis has increased to 2164. These electric taxis consist of five vehicle models provided by four EV companies.

In order to better monitor and manage these NEVs, EVMSC was built and put into operation in 2012. As Figure 1 shows, this platform conducts real-time monitoring of electric taxis, electric buses, electric trucks as well as rental BEVs in Beijing area. The monitoring data cover the driving information including the position, speed and the parameters of EVs including cell voltages, SOC state etc. The role of this platform is to monitor and collect the running data and conduct in-depth analysis and research through big-data techniques. It can also obtain the fault information of electrical control system, power battery and electric motor, then it will give early alarm to the drivers according to the fault level.

To study the operation condition and influencing factors of driving mileage of EVs, the historical operation data of electric taxis, including vehicle model, driving mileage, speed and charging information, are derived from the big data platform for further analysis.

**Analysis of Operation Condition**

Take the historical monitoring data in 2016 for example to analyze the operating condition of electric taxis. In 2016, a total of 6009 vehicles were monitored by the platform, with an increase of 49% compared with that of last year. Among them, the number of taxis accounted for 36%. In the aspect of driving, according to the whole situation, the daily driving mileage of electric taxis change within the range of 0-600km and the mean of the whole year is 134.8km. The median of average daily driving mileage in each month changes within the range of 120-150km. Specifically, in summer, the median of average daily driving mileage is the highest of the year, which reaches 144km, and in winter, the value is significantly lower than other seasons, which is about 122km. The daily driving time is about 7 to 10 hours and the average length of single travel is about 105 minutes. In the aspect of charging, the charging time of electric taxis is mostly in the period of 21:00-02:30 and 12:30-15:30, that is to say, many drivers of electric taxis chose to charge at night and noon. The daily charging capacity varies from 20 to 30 kWh, which is closely relative to the battery capacity.
Influencing Factors

According to the analysis of historical operation data, we find that the driving mileage of electric taxis fluctuate every day. To illustrate this fact more clearly, the daily driving mileage data of research vehicle from Jan 1, 2016 to Dec 31, 2016 are derived from the platform and shown in Figure 2. It can be seen that the average driving mileage of one day in the year is 254.6km, and the daily driving mileage varies from 44 to 366km with a maximal difference of 322km. Through the work we have done in this paper, we find that the driving mileage is affected by many factors including ambient temperature, driving patterns and charging behaviors, etc. In the remainder of this paper, taking the monitoring operation data of E200EV from EVMSC in 2016 for example, the influence of these three factors mentioned above are explored.

![Figure 1. Electric Vehicles Monitoring and Service Center of Beijing (EVMSC).](image1)

![Figure 2. The daily driving mileage of research vehicle in 2016.](image2)

Ambient Temperature

The ambient temperature may greatly influence the energy consumption and driving mileage since the performance of power battery can be easily affected by temperature. To demonstrate this fact, the temperature data of each day in Beijing area in 2016 was collected and presented in Figure 3. The shaded area indicates the range of temperature changing in a day, and the solid line represents the change of average temperature of each day in the year. Worthy of note is that these temperature data are derived from Weather China [4], which contain hourly averaged climatic data for 365 days of the year across China. To investigate the relationship between ambient temperature and driving mileage, the operation data of 10 research vehicles are collected from EVMSC, than these data are used to calculate average daily driving mileage. According to the information of time, temperature data are added to the operation data of research vehicles.

After preprocessing of the data, the scatter diagram of driving mileage versus the ambient temperature is shown as Figure 4. The solid line represents the Gaussian regression result between these two factors, which shows that when the ambient temperature rises or drops from around 20°C, the driving mileage decreases as expected. It is known that as the ambient temperature decreases, the ability to deliver and receive current of battery is reduced, and this ability goes up as the temperature rises. According to the research did by Gong X et al., the battery performance of EV is limited by the polarization effect at low temperatures. The result of research indicates that Li-ion batteries may truly lose 10% capacity at subzero temperatures [5]. In addition, when the ambient temperature exceeds the comfortable level of the human body, drivers will use the air conditioner (AC) more frequently, which will consume a significant amount of energy. As the conclusion drawn by Samadani E et al. indicates, the use of AC can cause on average 19% range reduction of EV under standard drive cycles. Also, the battery experiences higher capacity degradation when AC is operating; on average 10% under US06 and HWFET drive cycles [6]. What’s more, at a low temperature, the degradation of battery performance and endurance mileage of EV may get drivers more anxious. Owing to this, although there is still adequate residual energy, drivers may stop driving to make sure that they won’t stop on the halfway.
Driving Patterns

Driving patterns exhibited in a real world are the product of the instantaneous decisions of the drivers to cope with the driving environment, especially how drivers apply pressure on acceleration and brake pedal. Different driving patterns will make an obvious difference on the energy consumption and driving mileage. An aggressive driving pattern will increase the energy consumption and reduce the autonomy of the battery, while a calm driving pattern will extend the driving mileage to a certain degree [7].

The acceleration during driving process is used to evaluate the aggressive level of driving patterns. The instantaneous acceleration is computed directly from the measured speed data using numerical differentiation. Figure 5 shows a period of driving process of research vehicle from 7:40:00 to 7:50:00 on Jun 27, 2016, the shaded part represents the variation of speed, and the solid line represents the acceleration of each moment. The data acquisition frequency is 1HZ.

![Figure 5. Speed and Acceleration of research vehicle as a function of time.](image)

Figure 6. Acceleration distribution curve of three typical kind of driving patterns.

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Figure 7. The scatter diagram of SD of acceleration versus daily driving mileage.

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The driving patterns will be classified to calm, normal and aggressive according to the SD of acceleration. Greater SD of acceleration generally means higher aggressive level of driving patterns. One year of historical driving data of electric taxis are used to study the classification of driving patterns. Figure 6 shows the SD of acceleration and distribution of three kind of driving patterns. It can be seen in the results that the distribution of acceleration tends to be more dispersed with increase of the value of SD. That generally means the driver has more accelerating and decelerating behaviors during driving process, in other words, the driving pattern is more aggressive.

In order to exclude the influence of ambient temperature, the driving data of research vehicle in June and July are used to study the influence of driving patterns. The SD of acceleration and driving mileage of each day in this period are calculated and shown in Figure 7. As the result shows, there exists an obvious negative correlation between SD of EV acceleration and daily driving mileage. That is to say, higher aggressive level of driving patterns always mean less driving mileage.

Charging Behaviors

Charging behaviors, including charging frequency and charging capacity, will influence the driving mileage significantly. Reasonable arrangements for the charging operation can extend the mileage to a certain extent. Figure 8 shows a scatter diagram of the daily driving mileage versus daily charging frequency and the result of linear regression between these two factors. It can be noticed that the more frequent an electric taxi charges, the longer it travels. In particular, the electric taxis charge 3 times every day travel about 100km more than twice and 175km more than once a day.

Obviously, the driving mileage is closely related to the energy consumption, so the capacity charging in a day will significantly influence the daily driving mileage. A scatter diagram of the daily driving mileage versus daily charging capacity in summer and winter is respectively shown as Fig. 9. The solid line represents the linear regression between these two factors. It can be seen that the driving mileage increases with the increase of charging capacity. It can also be noticed that with the same daily charging capacity, the daily driving mileage in summer is more than that in winter.

Based the analysis of historical charging data, it can be found that drivers of electric taxis chose fast charging nearly every two days and slow charging every day. Overall, the ratio between fast charging and slow charging is about 1:2.5. The reasons for this situation can be concluded as follows: On the one hand, the fast charging stations are still inadequate in public areas. On the other hand, the cost of slow charging at home is lower than fast charging in public area, so drivers tend to chose the former.

Others

Besides the factors mentioned above, there are several other factors, including vehicle model, driving district and driving date, can also influence the driving mileage of electric taxis. These three factors are analyzed in this section briefly.

Up to now, electric taxis are put into use in 10 districts of Beijing, including Daxing, Huairou and Fangshan, etc. The Box-plot presented in Figure 10 shows the distribution of daily driving mileage in these districts. It can be seen that the distribution of driving mileage in different districts is obviously
different. This result may be caused by the difference of economic development and the demand of traveling by taxis among different districts.

![Figure 10. Daily driving mileage in different districts in Beijing.](image1)

![Figure 11. Endurance mileage and daily driving mileage of five vehicle models.](image2)

![Figure 12. Daily driving time and driving mileage in workdays, weekend and holiday.](image3)

Due to the difference of battery capacity and vehicle configuration, five models of electric taxis used in Beijing have different performance in daily driving mileage. As the result shown in Figure 11, the daily driving mileage is relative to the endurance mileage closely. Generally, the daily driving mileage accounts for close to 75% of endurance mileage.

As for driving date, the driving mileage in workdays, weekend and holiday is calculated respectively and shown in Figure 12. As the result indicates, the driving time and driving mileage of different date can be ranked in descending order as workdays, weekend and holiday. The reason may be that people tend to choose electric taxis more frequently in workdays to commute between work place and home. During weekend and holiday, some people tend to go for a farther trip by other means of transportation.

**Conclusions**

This paper analyzed the operation data and studied the variation of daily driving mileage of electric taxis of Beijing in 2016. Based on the analysis of historical data collected from EVMSC, the main influencing factors of driving mileage of electric taxis are presented. First of all, the influence of temperature can be summarized as: the driving mileage is maximum when the ambient temperature is around 20°C, and it will decrease with temperature rising or dropping. Secondly, the aggressive driving behaviors will increase the consumption of energy and decrease the driving mileage, while a calm driving pattern will extend the driving mileage to a certain degree. Lastly, the driving mileage increases with the increase of charging frequency and charging capacity. It is worth noting that the charging behavior is significantly influenced by the construction of charging infrastructure and the
charging fee standard. Beyond that, some other factors, including vehicle model, driving district and driving date, can also influence the driving mileage.

According to the results of this work, drivers of electric taxis can take appropriate measures to extend the driving mileage as possible. For example, decreasing the frequency of rapid accelerating or decelerating behaviors and keeping calm driving pattern. The government should speed up the construction of charging infrastructure and lower charging fee standard properly to satisfy the charging demand of EVs consumers. Furthermore, a driving assistance system can be developed based on the aforementioned analysis. The system will provide driving suggestion to drivers and help them adjust driving behaviors to ensure the best conditions of EVs and extend the driving mileage.

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References


