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A completive survey study on the feasibility and adaptation of EVs in Beijing, China

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HIGHLIGHTS

- EVs have been greatly developed with a series of encouraging policies.
- The maxi mileages and braking performance still needs further improvement.
- More residential and public charging piles should be in the plan and design.
- APP oriented information of charging station need to be researched and developed.

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ABSTRACT

The private motor vehicles are significantly important means of transportation in modern lifestyle, however, these also contribute to a large proportion of the total air pollution and primary energy consumption. In order to develop green transportation system, it becomes imperative to use integrated technologies to achieve reduced emissions and utilize renewable energy. Electric vehicles (EVs) have been considered as one of these technologies to transform the traditional vehicle mix. However, the uptake of EV has been debated on factors like cost, performance (autonomous mileage), charging point infrastructure construction, energy saving, policy and end users' adaptation. Present study investigates the technology feasibility (which usually refer to EVs' cost, EV charging, supplier's customer services quality, EV travel performance) and users' adaptation of EV in Beijing, which is a key driver for the EV uptake into the Beijing transportation system. The relevant data have been collected and analyzed in the form of questionnaire survey around all of these factors. While considering the user perception and satisfaction, safety of charging and energy bills have also been investigated. According to the data analysis, it has been found the policy of 'No traffic restrictions for EVs' (the traffic restrictions means for certain date, from Monday to Friday the motor vehicles with the last register number of 1 and 6, 2 and 7, 3 and 8, 4 and 9, 5 and 0, are restricted to travel, respectively), the availability of the charging infrastructure and technical support are the most significant factors affecting the users' opinions on using EVs.

1. Introduction

In 2013, amongst top 10 air polluted cities in the world, seven of them were in China [1] with Beijing as one of the most heavily polluted city mainly contributed by industry and transportation sectors. Since past ten years, the number of private vehicles in Beijing has rapidly increased to 5.5 million, constituting 70% of the total energy consumption in transportation sector [2]. The fast expansion of the privately-owned vehicles has not only induced the energy crisis, but also caused a heavy impact on the air quality. According to the published statistics data in 2015, the transportation sector was responsible for 15% of the total CO_2 emissions around the world [3]. It is worse in Beijing that the emissions from the vehicle contributes 25% of the city's total CO_2 emissions, grievously higher than the world's average figure [4].

In order to address this problem, the city government in Beijing has taken a series of remedial actions. The most effective method to reduce the levels of emission is the traffic restrictions (TR) based

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on the last digit of vehicle registration numbers (Traffic Restrictions is a method that the Beijing City Government implemented to reduce the traffic congestion and reduce the CO_2 emissions by restricting private vehicles with the last digit of registration number e.g. 1 and 6, 2 and 7, 3 and 8, 4 and 9, 5 and 0, are restricted to travel on week days from Monday to Friday respectively). During the period of the 20th to 29th, August, 2015, by applying this method, the average PM2.5 was 17 $\mu g/m^3$ for ten days, and dropped by 74.5% comparing to the pervious testing results [5]. Although the above method has led to excellent results, however reducing the vehicle emission by restricting vehicles travelling would not solve the problem fundamentally.

Therefore, developing new strategy to use energy and carbon efficient vehicles is another alternative put on the agenda. Vehicle with battery, super capacitor can achieve reduced emission [6], and reduce the dependency on the fossil energy such as petro oil, diesel oil and natural gas. Also the electric energy for the Electric Vehicles (EV) could be generated by the renewable sources such as hydro energy waste thermal/geothermal energy, wind energy, solar energy, bio-energy and other non-fossil fuels. Therefore, replacing the traditional fossil fuel vehicles with EV could be a better option. Because of aforesaid advantages, the research on use of EVs become a hot topic in the automotive industry. By the end of 2015, there are various types of EVs in the world, such as hybrid electric vehicles, pure electric vehicles (EVs, including solar cars), fuel cell electric vehicles (FCEV), and hydrogen engine cars. But in China, only pure EVs have been promoted, for which the sale volume had reached to 350,000 units in 2015. In Beijing alone, this number has reached 28,900 mark one of the highest in China, supplied by 9 vehicles manufactures rolling out 14 electrical vehicle models [7].

In recent years, with the development of EV, many scholars have carried out researches on the purchase preference, battery technology, renewable energy integration, price, policy and EV charging station layout in the world [8–12] However, research on the adequacy of charging infrastructure, public's adaptation of EV, and people's attitude on EVs, are still under highlighted. Peng et al. [13] presents an overview of the economic dispatch and risk management of Plug-in hybrid electric vehicle (PHEV) in the electricity market. An orderly charging strategy to avoid overloading, flatten the load curve, increase stability and reliability of the electric grid was put forward, and the rationality of power distribution and power quality have been improved. Zhang et al. [14] used three binary logistic regression models to determine the factors that have impact on the consumers' acceptance of EVs, purchase time and purchase price. This contributes to the understanding of the consumer's purchase behavior of EVs and have important impact on the policies to promote EVs in China. Seixas et al. [15] and Verma et al. [16] analyzed the total cost of EVs from the perspective of the energy system, which includes the power sources technologies, alternative transport and fuels technologies, power transmission and distribution. They provided insight into the cost of integrating renewable energy technologies with EVs' charging. He et al. [17] studied the layout of the charging station in the urban area and explored how to optimally locate the public charging stations for the electric vehicles based on a road network. They mainly considered the drivers' subconscious adjustments, logistic decisions by considering the travel and the recharging, and developed a mathematical model to simulate the deployment of charging infrastructure and charging behaviors. Liu et al. [18] presented the interactions between the EVs and the renewable energy sources (RESs), under the three categories: cost-aware, efficiency-aware, and emissions-aware. Helveston et al. [19] compared the purchase preference of consumers between China and the United States. It is found that China's consumers are more willing to accept electric cars and they also believed that China was expected to develop the technology of EV to reduce the emissions from vehicles. The previous research provided a good theoretical background for this study to analyze the uptake and the development of EVs in Beijing. Moreover, some major factors of focus for the present study have been identified as given in Table 1.

In addition, there are several studies analyzing EVs' user's behavior in other countries. Ziefle et al. [42] identified influencing factors (gender and age group) on acceptance of EVs and exploring users' perceived benefits and drawbacks. Study claimed EVs survey methodology and assumptions [43]. Another study investigated the indicators (price, infrastructure, policy, socio-economic characteristics) that determined the consumers' acceptance regarding the use of EVs [44]. Drew [45] presented the status of consumer profiles, sales forecasts, market barriers and public policy of EVs in the US.

However, there is no published research particularly in Chinese context on the development of EV emphasizing on the user's feedback information to integrate the relevant impacting factors, issues, policies and the infrastructure for EVs, which will interact with each other. Present research considers collection of the real-life data and investigate the influencing factors such as EVs' performance, customer service quality, energy consumption, charging, relevant infrastructure, and policies for EVs. The EVs' performance and satisfaction of infrastructure support vary for different users as different individual user with specific purpose and requirement uses each EV. Furthermore, this study will explore the gap between the claimed EV performances by the manufacturer and the real-life feedback recognized by the practical users including the convenience, efficiency and the satisfaction. The results will contribute for better/more accomplished future policy making, the EV development, the infrastructure construction and also the sale strategy for EVs. A detailed survey has been conducted to collect all these important data and information.

2. Background of implement of EVs in Beijing

At present, in order to reduce the impact of air pollution caused by vehicle emission, Beijing Municipal Science and Technology Committee (BMSTC) and the Bureau of Finance announced 'The Pilot Scheme of the Subsidy for personal purchase of new EVs in Beijing' since May, 2011. This subsidy is on various scales based on the price of different types of EVs: the maximum subsidy with plug-in hybrid EVs is $7538/Vehicle and the highest subsidy for pure EVs is $9046/Vehicle. Besides, the price subsidy provided by the BMSTC and the Bureau of Finance, the Central Government also match fund the amount of subsidy. Therefore, the maximum subsidy amount can be claimed is $18,092 for buying a pure EV in Beijing [46]. Encouraged by this policy, the registered EVs number had reached 6000 in Beijing in 2014. Then in the first half year of 2015, the registered EVs had accumulated to 8822 in Beijing, among of them, 6555 EVs belong to the individuals and 1267 EVs belong to the institutions or private companies. With this development trend, the Beijing government expects that the EVs number will reach 170,000 in 2017 [47].

In addition, there are 185 charging stations with 1384 charging piles in Beijing according to the latest data provided by Beijing New EVs Services Institution, which has been set up and opened to the public since 13th, September 2015. The charging stations include 744 fast charging piles for taxis and 640 slow charging piles for private EVs. Fast charging pile could charge an EV within a reasonable short time but has some damage impact on the battery, and slow charging pile would charge the EV taking a longer period of time but with much less harm on the battery. Therefore, for most of the taxis driver they select the fast charging once their EVs run out of battery during their work time, but for the private