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Cost–benefit assessment and implications for service pricing of electric taxies in China

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ABSTRACT

This paper presents a methodology to assess the cost–benefit and develop the service pricing strategy of electric taxies in Shanghai, China. There are 4 kinds of electric taxi models being structured. The total life cycle cost model for cost–benefit assessment is developed with consideration of purchase cost, usage cost, and other operation cost. Three scenarios are defined, including gasoline price increasing, electricity price increasing, and battery cost decreasing. Then the service pricing model is proposed. The results indicate that the profitability of battery-swapping model is higher than that of the charging model. The taxi models with longer driving range have greater profitability than those with shorter driving range. With annually increasing rate of 8% of gasoline price, the electric taxi will obtain the same profit with the gasoline taxi in 5 years. With annually increasing rate of 20% of electricity price, the service price of electric taxies will rise by 1%. When the battery cost decreases by 49%, the service price of electric taxies will be 4% lower than that of gasoline taxies.

Introduction

Since the year 2009, China has become the world's largest car market by sales. It is forecasted that the sales volume would rise to 30 million by 2020 and the growth would last for a long time (Wang et al., 2011). The growing number of cars will lead to the increasing oil demand and greenhouse gas emission, which will pose a great challenge for the development of social economy and environment. Electric vehicles are considered as an effective technological innovation to reduce energy use and greenhouse gas emission, which has raised great attention among the government and car manufacturers (Granovskii et al., 2006; Hoyer, 2008). In China, the electric vehicle technologies are being promoted as securing the future of mobility. In 2012, the Chinese government issued the "Planning for the Development of the Energy-saving and New Energy Automobile Industry (2012–2020)," in which the electric vehicle has been chosen as the main strategic orientation to promote new energy vehicle technologies and thus develop Chinese automobile industry (The state council of the People's Republic of China, 2012). A series of policies to promote electric vehicle industrialization and commercialization have been introduced in recent years, including pilot demonstration projects (Ministry of Science and Technology (MOST), http://www.gov.cn/zwgk/2009-02/05/content_1222338.htm, 2009), production standards (Ministry of Industry and Information Technology (MIIT), http://www.miit.gov.cn/n11293472/n11293832/n11294057/n11302390/12427300.html, 2009), and purchase subsidies (National Development and Reform Commission and Ministry of Finance, http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201005/t20100531_320528.html, http://www.miit.gov.cn/n11293472/n11293832/n12843926/n13917042/15629217.html, 2010 and 2013). Some Chinese car manufacturers have already launched their EV models and made mass production plans, such as the BYD E6, BAIC E150, JAC iev4, Zotye 5008EV, Roewe E50, and Shanghai GM Springo EV. In some cities of China, EV plays an important role in public transport areas. The electric taxi is one of the most important vehicle types for demonstration of public service vehicle fleets.

There are some studies in consumer awareness and purchase barriers of vehicle owners. Maris Yetano Roche (Yetano Roche et al., 2009) analyzed the consumers' attitudes and demands for electric vehicles with the quantitative methods, and the results indicated that the purchase price and usage cost are the most important factors for purchase decision of private consumers. Another survey by Tongji University has also come to the same conclusion (http://auto.sohu.com/s2011/tjdx1/index.shtml, 2011). They surveyed 2702 online consumers in China about the willingness to purchase electric vehicles through SOHU website. The survey implied that 80% of the interviewers considered the high purchase cost as the most obstructive factor and 90% considered the low usage cost as the most attractive factor in terms of purchasing an electric vehicle. Some studies have analyzed the overall costs of the electric vehicles. Christian Thiel (Thiel et al., 2010) calculated the total life cycle costs of electric vehicles and gasoline vehicles with the same class in terms of various driving range and gasoline price. The results showed that the electric vehicle had no

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cost advantage over gasoline vehicle. Andreas Schroeder (Schroeder and Traber, 2012) focused on the operation cost of the electric vehicle charging infrastructure and the calculation results showed that it was difficult to gain profit for charging infrastructure at present.

As for the electric taxi, Chuanfu Wang (Chuanfu, 2011), the president of BYD Auto, stated that the fuel consumption and emission of 1 internal combustion engine taxi equal to 10 private cars and the electric vehicle was more suitable to be applied in public traffic sector than private sector in the initial stage. Now there are 800 electric taxies of BYD E6 being demonstrated in Shenzhen. Theo Lieveni (Lieven et al., 2011) illustrated that 15.4% of taxi buyers would like to choose electric vehicles, which is higher than other sectors of vehicle purchase. There are two operation modes of the electric taxi in China: charging model and battery-swapping model, which are demonstrated in Shenzhen and Hangzhou, respectively. There are some unique characteristics of taxies, such as long driving range, non-fixed routes, and driven by economic interests. This study focuses on the cost–benefit and the service pricing strategy of electric taxies. We investigate different electric taxies with two operation modes and present a cost–benefit assessment methodology and the service pricing strategies for electric taxies.

In this study, the cost–benefit assessment is based on the model of total life cycle cost. The total life cycle cost (TLCC) of the electric taxi includes the purchase cost, battery repurchase/depreciation cost, charging/swapping cost, maintenance cost, insurance cost, and drivers' salary. It is assumed that the nominal lifetime of the traditional gasoline taxi (TG) is 5 years. Then the profits of the battery-charging electric taxi (TC) and battery-swapping electric taxi (TS) in 5 years are calculated in terms of different electricity prices to assess the cost–benefit of electric taxies. Finally, the service pricing model of electric taxies can be developed based on the calculation.

The whole calculation process can be divided into three parts:

1) Parameters of 5 vehicle models: The 5 vehicle models consist of 2 battery-charging electric taxies, 2 battery-swapping electric taxies, and 1 traditional gasoline taxi, which are developed based on the analysis of taxi operational and technical requirements. To determine the suitable battery capacity for each vehicle model, the vehicle dynamic simulation model is made by the Cruise Software to calculate the energy consumption of different electric vehicles. The parameters of the energy consumption, battery capacity, and curb weight of different vehicle models for TLCC calculation are determined in this part.
2) Cost–benefit assessment: The battery purchase cost, gasoline fuel price, and fuel consumption are predicted to calculate the TLCC of the 5 vehicle models in 5 years. A bottom up, component-based forecasting model of battery costs, and an ARIMA prediction model of gasoline fuel prices are developed. The Monte Carlo analysis model is made to calculate the TLCC of the 5 taxi models in 5 years nominal lifetime, and the profit results of TC and TS vehicle models are compared to the TG vehicle model based on scenarios of the residential and commercial electricity price.
3) Service pricing model of electric taxies: The service pricing model is developed in the scenarios of different gasoline prices, electricity prices, and battery costs. The electric taxi service price is calculated to make the profit of electric taxies equal to that of gasoline taxies in 5 years.

Power supply modes for electric vehicles

There are two modes for electric vehicles to obtain energy: the battery-charging model and the battery-swapping model.

The battery-charging model is the most general and feasible way for electric vehicle to charge at charging stations, parking lots, and garages. However, the charging time of electric vehicles is much longer than gasoline cars. In general, an electric vehicle can be fully charged in 6–10 h with 220 V power input, or 3–4 h with 380 V power input. Another method of quick charging can charge 50% ~ 80% of the capacity within 20 ~ 30 minutes (Lairong, 2011), yet it has bad effects on battery lifetime.

The battery-swapping model can effectively overcome the inconvenience caused by long charging time. In the electric taxi battery-swapping station of Hangzhou, it takes 5 minutes to manually swap the battery pack. In the battery-swapping station of the Better Place, it only takes 1 minute to finish the swap with automatic devices (Feng, 2012). In this model, the battery is owned by the battery-swapping station, and consumers only need to pay for the battery charging and battery depreciation cost with no purchase cost. This model is ideal for the electric vehicle power supply, yet it is difficult to make it widely applied due to poor compatibility of different battery types and high investment of battery purchase.

Requirement for taxi operation in Shanghai

Status of taxi operation in Shanghai

There are 50,683 taxies in Shanghai in the year 2012. The cumulative driving mileage for the taxi operation is 6.377 billion km, in which the service mileage is 3.984 billion km with revenues of 16.774 billion CNY (Zhixiong and Junxian, 2012). The empty-loading ratio of gasoline taxies is 38%. The average operation mileage of a taxi is 344.7 km per day. The average revenue is 4.21 CNY/km. More than 90% of the taxies are Santana of Shanghai Volkswagen based on the platform of Passat B2.

The property and management rights of taxies belong to the taxi operation companies (Yingying, 2009). Two drivers own one taxi and each of them works 15 days per month. The average driving time is 18.5 h per day and the average income of one driver is 6000 CNY/month (Sports College, 2011). The average vehicle speed is 19.2 km/h. Thus every driver works 277.5 h per month and the income is 21.5 CNY/h.

Taxi operation requirement of two power supply models

Taxi operation requirement of charging model

For the charging model, the electric taxi is fully charged by 380 V three-phase power for 3.5 h in order to improve charging efficiency. There are two charging scenarios for our vehicle model. The first one is the battery with large capacity such as BYD E6, which can be fully charged at night and obtained 30% capacity for 1 h quick charging in the daytime. The average driving time is 8.75 h when the battery is fully charged. The second one is the battery with mid-size capacity, which needs to be fully charged for twice in the afternoon and at night. The average driving time is 7.5 h when the battery is fully charged.

For the first charging scenario, the taxi is required to drive 17.5 h with 130% of the battery capacity, which means the driving mileage with full charge should be equal to 258 km (19.2 km/h × 17.5 h/130%). For the second charging scenario, the driving mileage with full charge is required to be 144 km (19.2 km/h × 7.5 h).

The driving range of electric taxies should be greater than the required driving mileage, which is determined to be 10% larger than the actual requirement. Thus, the driving ranges of the two scenarios are calculated to be 284 km and 158 km, respectively, which are named TC284 and TC158 for charging model taxies.

Taxi operation requirement of battery-swapping model

For the battery-swapping model, there is no need to determine the fixed charging time for electric taxies due to the short battery-swapping time. In this model, the battery capacity should be relatively small in order to make the swapping process efficient and safe. 100 km and 150 km are selected as the driving range of two swapping