CUSTOMERS' SELECTIONS BETWEEN PREMIUM ELECTRIC TAXIS AND LIQUEFIED PETROLEUM GAS TAXIS

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Abstract

Reducing roadside emissions is a common challenge in metropolitan cities. In Hong Kong, conventional liquefied petroleum gas taxis are one of the main contributors to roadside emissions as they operate on the streets 24 hours a day with a long daily driving mileage. Moreover, these taxis suffer from a severely poor service reputation. To enhance the environmental friendliness and service quality of the taxi industry, this study explores the market potential of operating premium electric taxis in the dispatching mode. A stated preference survey was conducted to 1410 taxi customers about their taxi-riding choices between premium electric taxis and conventional liquefied petroleum gas taxis. In total, 5640 observations were obtained and used to develop a series of binary logistic regression models with different model formulations for the determination of the significant factors influencing customers' selections. The findings indicate that walk time to and wait time for taxis were the most critical concerns to the customers, and they were more willing to take premium taxis if their journey distance was longer and their desired improvement on taxi service quality was greater. The socio-demographic status of taxi customers also influences their choices. The associated policy implications are discussed for promoting taxis with better service quality and fewer roadside emissions. The findings provide some policy insights to other international cities that have a similar taxi market in Hong Kong.

Keywords: roadside greenhouse gas emissions, battery electric vehicles, public transport service quality, premium taxis, taxi customers' selections.

1. Introduction

As a highly urbanized and densely populated metropolitan, Hong Kong is facing a critical challenge from severe roadside emissions. Excessive air pollutants and greenhouse gases, including Carbon Dioxide (CO_2), Carbon Monoxide (CO), Volatile Organic Compound (VOC), and Nitrogen Oxides (NO_x), are emitted by the conventional vehicles with internal combustion engines (Environmental Protection Department, 2017; Clean Air Network, 2017; Yang et al., 2019). The Hong Kong government has set to reduce the unit greenhouse gas emissions from the 2005 level of 6.0 ton/person to less than 4.5 ton/person in 2020 (Environment Bureau, 2017). However, the latest figure in 2015 was still high at 5.7 ton/person (Environmental Protection Department, 2017). The environmental target cannot be achieved unless more substantial efforts and commitments are made, in particular on road traffic.

To reduce the roadside air pollutants and the resultant CO_2 emissions, previous research examined the usage of Battery Electric Vehicles (BEVs) (Steinhilber et al., 2013; Buekers et al., 2014; Hao et al., 2014; Bonges III and Lusk, 2016; Teixeira and Sodré, 2018). Recently, the applications of BEVs to the taxi industry have been extensively studied and investigated (Gacias and Meunier, 2015; Yang et al., 2016; Kim et al., 2017; Wang et al., 2018; Hagman and Langbroek, 2018; Gawron et al., 2019). In Hong Kong, taxis operate on streets 24 hours a day and mostly cruise on streets to search for taxi customers (Wong et al., 2014). This operational mode leads to the long daily driving distance and high emissions although their fleet size is small (Transport Department, 2017). Nearly all taxis are Liquefied Petroleum Gas (LPG) taxis, which should produce few emissions in principle. However, the older LPG taxis with a poorly maintained catalytic converter emitted more than double hydrocarbons and CO than diesel counterparts (Ning and Chan, 2007), and are also one of the major contributors of NO_x pollution (Lau et al., 2012). Therefore, replacing the existing LPG taxis with electric taxis (eTaxis) could effectively alleviate roadside air pollution in Hong Kong. Currently, Shenzhen and Beijing are operating their large-scale eTaxi fleets, which are highly subsidized by the government (Li et al., 2016; Zou et al., 2016; Zhang and Zhao, 2018). Amsterdam is offering airport taxi services by eTaxis with financial support from the government for purchasing BEVs at a lower price (Netherland Enterprise Agency, 2015). New York City has been replacing one-third of the current taxi fleet with eTaxis by 2020 and offering direct subsidies to the respective taxi drivers (NYC Taxi & Limousine Commission, 2013). Based on these international experiences, we believe that introducing eTaxis has the potential to achieve the emission targets of Hong Kong. Yet, the taxi industry has only received limited support from the government in lowering their roadside air pollutants and the resultant CO_2 emissions. Therefore, more emphasis should be placed on enhancing the environmental friendliness of the taxi industry.

Besides, Hong Kong taxis are criticized for their poor service quality (Wong and Szeto, 2018). Transport Advisory Committee received 7253 complaints on taxi service quality in 2006, and the number increased to 10759 in 2017, accounting for nearly half of all complaints lodged against public transportation. The top five subjects of complaints were (1) the refusal of hire, (2) poor service attitudes, (3) overcharging, (4) intentional detours, and (5) improper driving (Transport Advisory Committee, 2017). The poor service quality of the taxi industry is often attributed to the lack of competition, supervision, and standards. The local taxi associations attempted to upgrade the service quality but in vain. Currently, taxi operators are encountering competition with ride-sourcing operators (e.g., Lyft and Uber), which provide similar transportation services with a wider range of service quality. For instance, Uber offers differentiated service levels targeting the budget, intermediate, and premium customers with different levels of willingness-to-pay. Several studies have investigated taxi operations with various service standards and confirmed the presence of heterogeneous customer demand for differentiated taxi services (Rayle et al., 2016; Nie, 2017). There is a market potential to introduce a premium taxi service operating by well-trained and attentive drivers with luxurious vehicles for a portion of taxi customers with a higher expectation of service quality. Premium taxis can be observed in the taxi industries worldwide (e.g., Melbourne, Sydney, Tokyo, and Singapore). Wong et al. (2008) adopted the concept of premium taxis in developing their model, assuming that the high-income (lower-income) customers have a higher (lower) value of time and prefer to take luxury (normal) taxis. Nonetheless, no empirical evidence exists to confirm the assumed customers’ preferences in a taxi market with differentiated services, until the Hong Kong government conducted a study on premium taxis in 2016 (Legislative Council, 2016). The results showed that if the fare were 30% to 50% higher, 40% of the respondents would select either the premium or conventional service, and about 9% of them would certainly select the premium service. However, that study only gave a nominal fare increase level to the respondents without considering any other trip attributes (e.g., walk time to and wait time for taxis) and any environmental aspects. The findings cannot help to accurately estimate the demand and supply equilibrium in a taxi market with differentiated services.

To increase the environmental friendliness and service quality, this study intends to explore an alternative taxi operational design – **premium eTaxis in the dispatching mode**. It has the potential to uplift the service standard of taxis, serve the market niche for higher-quality taxi services, and alleviate the environmental impact of taxi movements. The improvement on service quality by introducing premium eTaxis is threefold: (1) The newer and quieter BEVs provide more comfortable traveling experiences to the customers and enhance their level of satisfaction; (2) The taxi drivers of premium eTaxis offer more polite services, help customers boarding/alighting, and assist in loading/unloading luggage; and (3) taxi orders are assigned to taxi drivers based on the information provided by global positioning system (GPS) devices. As such, the majority of the common disputes and complaints between taxi customers and drivers (e.g., refusal of hire, overcharging, and intentional detours) can be resolved. In addition, the dispatching mode makes recharging opportunities for eTaxis between order assignments. Using the latest fast-charge technology and high capacity lithium-ion batteries, BEVs have enough power for traveling up to 100 km in 10 min charging. Taxi drivers can recharge their premium eTaxis several times a day when they are waiting at taxi stands for customers. It mitigates taxi drivers' concerns of excessive recharging time, the reduction in operational hours, and insufficient driving range.

This research uses Hong Kong as a case study to find out the customers' acceptance of premium eTaxis, and how fare increase and other trip attributes may affect their decisions, which has yet to be covered by existing literature. We conducted a stated preference survey to taxi customers in Hong

Kong aiming to capture the factors that are influential to their travel decisions. To further understand the market niche and to capture how different settings of a premium service may affect taxi customer choices, we included two premium options in the survey with a standard premium and an advanced premium eTaxis. Binary logistic regression models were developed and calibrated to examine their choice behavior. Recommendations and policy implications are discussed to introduce an alternative taxi option to taxi customers with a higher awareness of environmental protection and a higher expectation of taxi service quality.

The contributions of this paper include the following:

(1) It suggests an alternative taxi operational design to enhance the environmental friendliness and service quality of the taxi industry;

(2) It develops binary logistic regression models to determine the important factors that influence customers' selections between premium eTaxis and conventional LPG taxis with different lengths of taxi trips and types of vehicles; and

(3) It gives policy insights and investigates how differentiated services can help to capture more taxi customer demand and promote greener transportation.

The remainder of this paper is organized as follows. Section 2 depicts the data collection procedures and provides an overview of the socio-demographic characteristics and travel patterns of the respondents; Section 3 presents the study methodology; Section 4 discusses the model results and provides policy insights and implications, and Section 5 concludes the paper and recommends some future research directions.

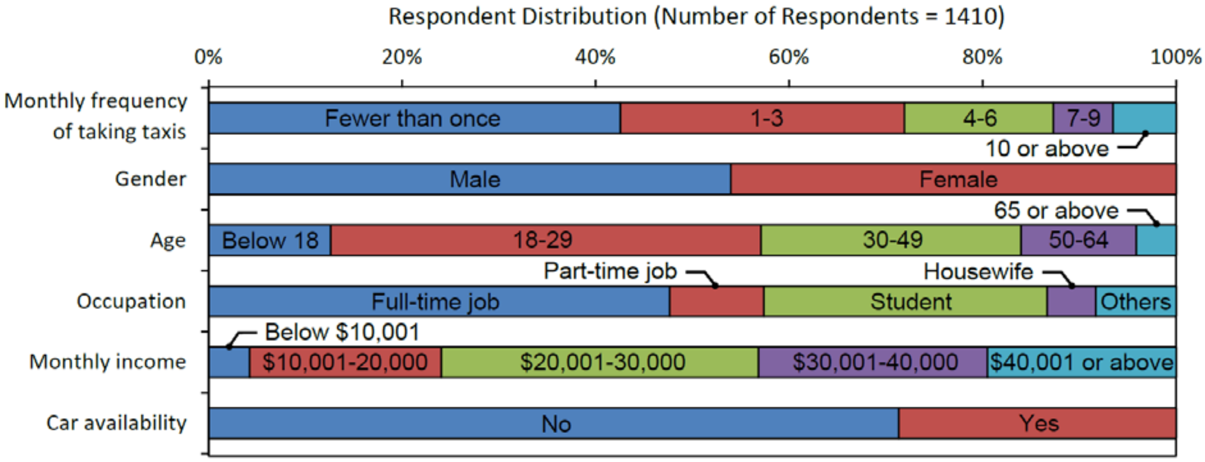
2. DATA

2.1 Data Collection

An on-street questionnaire survey was conducted in June and July 2017. Key locations with expected high concentrations of taxi customers were selected, including taxi stands, business districts, residential estates, and popular shopping areas across Hong Kong. We interviewed 1410 taxi customers successfully, in which the overall response rate was about 37%. No special events or incidents that could interfere with the quality and reliability of the interviews occurred during the survey period. The questionnaire asked for the socio-demographic characteristics and travel patterns of the respondents, their views and willingness-to-pay on replacing conventional LPG taxis with premium eTaxis for less roadside emissions and better service quality, and their selections in hypothetical scenarios.

2.2 Customers' Socio-demographic Characteristics and Travel Patterns

Figure 1 shows the socio-demographic characteristics and travel patterns of the respondents. About 60% of the 1410 interviewed taxi customers made at least one taxi trip in recent months of the interview day. It confirms that our study covered a wide spectrum of people with different frequencies of taking taxis. During the face-to-face discussions with the infrequent taxi customers, we learned that poor taxi service quality was one of the major reasons adversely affecting their decisions of taking taxis. Taxis providing a premium service may improve their willingness-to-travel. It is noted that 54% of the respondents were male, and 71% of them were between 18 and 49 years of age. Their median household monthly income lay in the group of HK$20,001-30,000. About their occupation status, 57% had either a full-time or a part-time job, while 29% were students. More than two-thirds of their families did not own a private car. The survey results reveal that the most common taxi trip purposes were going to and from work/school, attending social activities, and shopping or entertainment trips. The top reason for taking taxis was their timeliness, where over 60% of respondents took a taxi when they were in a rush. Less than 5% reported that the level of comfort was a reason for them selecting a taxi. For taxi-hailing behavior, since the local taxis were primarily operating in the cruising market, street hailing was the most frequent way for the respondents to meet a vacant taxi, followed by waiting at taxi-stands. Taxi-dispatching is not common. Notably, only 7% of the respondents had a habit of using taxi-dispatching services (including telephone orders and taxi-calling apps), which could be explained by the illegal status of the ride-sourcing platforms (e.g., Uber) in Hong Kong and the low market penetration rate of other legal taxi-calling platforms. Respondents used taxis throughout all periods of a day, during which the highest demand occurred in the morning peak. This corresponds to the most common trip purpose for choosing the taxi service.



Trip purposes	Frequency and proportion
Going to work/school	522 (37.0%)
Going back from work/school	224 (15.9%)
Shopping and entertainment	285 (20.2%)
Visiting friends and relatives	216 (15.3%)
Social activities	354 (25.1%)
Dining	99 (7.0%)
Medical purpose	190 (13.5%)
Others (e.g., business trips, escorting children to school)	122 (8.7%)

Reasons for taking taxis	Frequency and proportion
Convenience	627 (44.5%)
Level of comfort	65 (4.6%)
Adverse weather	255 (18.1%)
In a rush	884 (62.7%)
Not familiar with the local roads	126 (8.9%)
Carrying heavy baggage	147 (10.4%)
No other suitable public transport mode to destination	216 (15.3%)
Others (e.g., travel with children, elderly or disabled people)	51 (3.6%)

Most frequent ways of hailing taxis		Frequency and proportion
Street hailing		1002 (71.1%)
Waiting at taxi stands		333 (23.6%)
Taxi dispatching	Ordered by phone	112 (7.9%)
	Ordered by smartphone apps	94 (6.7%)

Most frequent periods of taking taxis	Frequency and proportion
Morning peak (6am to 10am)	568 (40.3%)
Noon inter-peak (10am to 5pm)	503 (35.7%)
Evening peak (5pm to 9pm)	414 (29.4%)
Mid-night inter-peak (9pm to 6am)	389 (27.6%)

Figure 1. Socio-demographic characteristics and travel behaviors of interviewed taxi customers

Figure 2 presents the respondents' views and their willingness-to-pay on replacing conventional LPG taxis with premium eTaxis for fewer roadside emissions and better service quality, respectively. The respondents showed an overwhelming agreement on replacing some or all of the existing taxis with cleaner eTaxis. For the respective customers' willingness-to-pay, 66% accepted fare increases up to 10% when LPG taxis were replaced with eTaxis, and 30% accepted fare increases up to 20%. These values were lower than the other studies on willingness-to-pay for environmental causes (Shao et al. 2018; Park and Yoon, 2017). It gives us an insight that the scheme of electrifying the current taxi fleets may not be successful if it only reduces roadside emissions but not improve the service quality at the same time. For the current taxi service quality, the respondents were asked to rate the current and desired taxi service qualities from 0 (which represents very dissatisfactory) to 10 (which represents very satisfactory). The mean score of the *current* taxi service quality was 5.56, slightly above the passing score of 5. In contrast, this mean score was close to the lower limit of 95% confidence interval for the *desired* taxi service quality (5.47), which clearly shows the dissatisfaction among the taxi customers and a large gap in meeting customers' expectations. This shortfall further indicates the need for providing a premium taxi service to taxi customers with a higher expectation. To achieve the desired taxi service quality, the majority (64%) of the respondents were willing to pay higher fares up to 10% more, whereas 31% were willing to pay between 10% and 20% more.

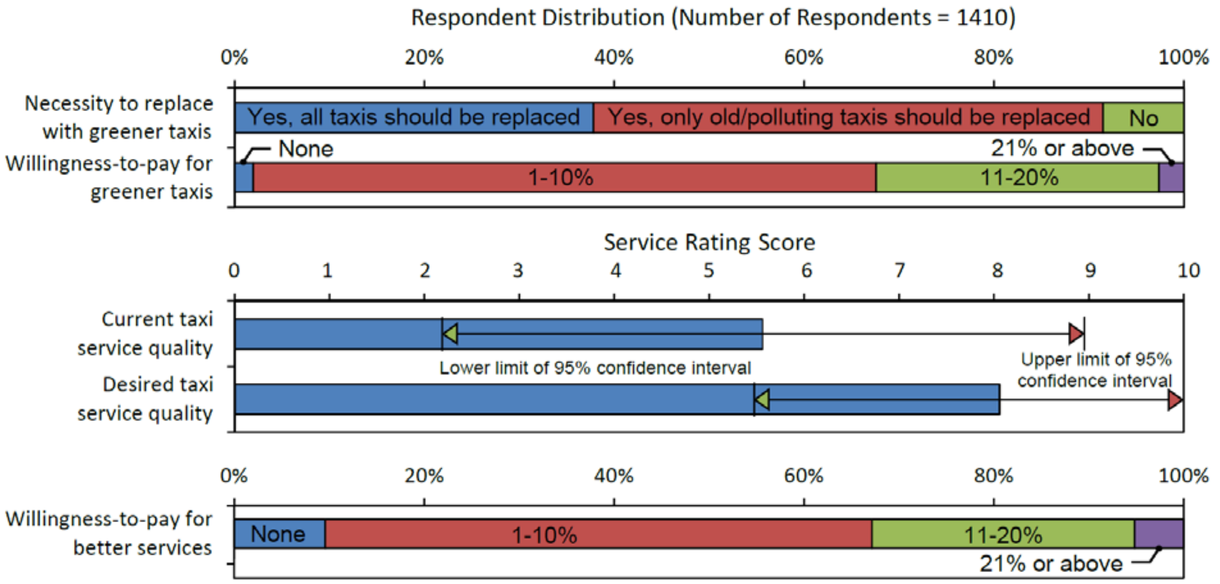


Figure 2. Respondents' views and willingness-to-pay on replacing conventional LPG taxis with premium eTaxis for less roadside pollution and better service quality

The attitudinal survey initially establishes that (1) the customers recognized the environmental and service deficiencies of the existing taxi operations, (2) there was a need for greener taxis and better services, and (3) the customers were willing to accept a higher fare. Models are developed in Section 3 to explore to what extent do fare increase, changes in wait times, and other trip attributes affect taxi customers' acceptance of the proposed premium eTaxi service.

2.3 Stated Preference Survey

Table 1 tabulates the attribute levels used in the experimental design. The respondents were asked to make binary choices between a premium eTaxi and a conventional LPG taxi in four hypothetical situations. The explanatory variables associated with the trip characteristics given to the respondents were: (1) walk time to a hailing or boarding location, (2) on-street wait time at the pick-up location before boarding, (3) off-street wait time (e.g., at home, in the office, or at the other convenient places before the ordered taxi's arrival), and (4) taxi fare. The first three time-specific attributes were collectively regarded as pre-boarding times required to meet a vacant taxi. Considering the different operations of cruising and dispatching modes, we assumed that customers would hail conventional LPG taxis on streets, and order premium eTaxis before they travel. When hailing a conventional LPG taxi, customers would walk to a location and wait for a vacant taxi to come by. When ordering a premium eTaxi, customers would wait at their origins and walk to a pick-up location when the taxis had arrived. Since the premium eTaxis could provide a service to meet the customers at a designated pick-up location, their on-street wait time was negligible. Walk time was assumed to be longer on average for conventional LPG taxi trips as the customers tended to walk to the main roads or places with a higher anticipated chance for vacant taxis (Wong et al., 2015), and shorter for the premium eTaxis as the vehicles could be dispatched to their origins.

The customers' selections between a premium eTaxi and a conventional LPG taxi were potentially affected by the length of a taxi trip and the type of vehicle (it reflects different levels of comfort and service qualities). Therefore, we incorporated these two elements in the stated preference survey for the heterogeneous responses from the interviewed taxi customers.

Table 1. Attributes and levels used in the stated-preference survey

Explanatory variables		Levels		
		Conventional LPG taxis (Toyota Crown)	Standard premium eTaxis (BYD e6)	Advanced premium eTaxis (Tesla Model S)
Walk time (min)		5, 7, 9	2, 4, 6	2, 4, 6
On-street wait time (min)		5, 10, 15	0	0
Off-street wait time (min)		0	12, 18, 24	12, 18, 24
Taxi fare (HK$)	Short trip (5 km travel)	40	45, 50, 55	60, 65, 70
	Long trip (15 km travel)	100	110, 120, 130	130, 140, 150

In Hong Kong, taxi fare was nonlinearly increasing with the travel distance and wait time, in which the unit charge of a short trip was higher than that of a long trip. As in 2017 during the survey period, the fixed start fee was HK$24. After the first 2 km, the fare was increased by HK$1.7 for every additional 200 m or 1 min wait time or part thereof. The increment was reduced to HK$1.2 after the fare is equal to or greater than HK$83.5, equivalent to a taxi trip longer than 10 km. Therefore, in our stated preference questions, the lengths of a sample short trip and a sample long trip were defined as 5 km and 15 km, respectively. The existing conventional LPG taxis in the market were Toyota Crown. The two proposed types of vehicles for premium eTaxis were BYD e6 (as the standard premium eTaxi) and Tesla Model S (as the advanced premium eTaxi). They are the most common electric vehicle models in Hong Kong, so the respondents could have a better understanding of the hypothetical scenarios and provide a more reliable choice decision. BYD e6 was adopted in the 2012 trial of eTaxis in Hong Kong and 48 eTaxis were introduced to provide normal taxi service in the cruising mode. Unfortunately, because of their insufficient driving range, excessive recharging time, and limited charging facilities at that time, the incomes of taxi drivers were significantly reduced. All these eTaxis do not provide services anymore (Environmental Protection Department, 2015). BYD e6 is currently used in the nearby city of Shenzhen, where it has the world's largest charging station with 637 fast-chargers to power all eTaxi fleet. Tesla Model S is the eTaxi choice of Amsterdam for the airport taxi service (Netherlands Enterprise Agency, 2015), and the most popular BEV choice of private vehicles in Hong Kong. It possesses a high-end market image and it is more luxurious than BYD e6. Both models have track records providing taxi services internationally. Therefore, we consider these models are appropriate to represent the standard premium eTaxi and the advanced premium eTaxi, respectively, in the stated-preference survey. Taxi drivers' service standards were defined to be the same for both vehicle types, including well-trained and attentive drivers, luggage handling, and door-opening service. The premium eTaxis also provided onboard amenities such as audio/video equipment, wireless internet connection, chargers, and multiple payment channels (e.g., credit card and e-payments). The corresponding taxi fares of the premium taxi options were different in the experiment. The hypothetical fare of standard premium eTaxis ranged from about 10% to 30% increases, and the hypothetical fare of advanced premium eTaxis ranged from about 30% to 50% increases in the fare of conventional LPG taxis.

A fractional factorial design was adopted and generated 108 scenarios for the stated preference questions. These scenarios were sorted into two groups of questionnaires by different premium eTaxi vehicle types. In each questionnaire, the respondents were presented with either the standard premium eTaxi (BYD e6) or the advanced premium eTaxi (Tesla Model S) as the vehicle type of premium eTaxi, and they were asked to select between one of the premium eTaxis and a conventional LPG taxi for both trip lengths in each of the four hypothetical games (two were short trips and the other two were long trips). The collected samples were evenly distributed, in which 689 (49%) respondents participated in the first group of questionnaires of standard premium eTaxis and 721 (51%)

participated in the second group of questionnaires of advanced premium eTaxis. As four independent decisions were made by each of the 1410 respondents, 5640 observations were obtained for model development in the later stage. A sample questionnaire of standard premium eTaxis is provided in the Appendix.

3. METHOD

3.1 Binary Logistic Regression Model

The respondents were requested to select between a premium eTaxi (either a standard or advanced premium eTaxi) and a conventional LPG taxi based on walk time, off-street and on-street wait times, taxi fare, the length of the taxi trip, and the type of premium eTaxi. Binary logistic regression models were developed using the assumption that each individual attempts to maximize his/her overall utility (Agresti, 2006), which take the following form:

$$P_i = \frac{1}{1+\exp\left(-U_i\right)}, \tag{1}$$

where P_i denotes the probability of an individual taxi customer *i* who selects a premium eTaxi (either standard or advanced premium eTaxi) in a hypothetical situation. U_i^l denotes the deterministic utility function, which captures the attributes affecting customers' selections. A higher utility means a larger probability of a premium eTaxi being chosen. The utility function can be expressed as

$$U_i = \alpha_{\mathrm{W}}\left(W_{\mathrm{p}} - W_{\mathrm{c}}\right) + \alpha_{\mathrm{G}}\left(G_{\mathrm{p}} - G_{\mathrm{c}}\right) + \alpha_{\mathrm{H}}\left(H_{\mathrm{p}} - H_{\mathrm{c}}\right) + \alpha_{\mathrm{F}}\left(F_{\mathrm{p}} - F_{\mathrm{c}}\right) + \mu, \tag{2}$$

where $\left(W_{\mathrm{p}} - W_{\mathrm{c}}\right)$, $\left(G_{\mathrm{p}} - G_{\mathrm{c}}\right)$, $\left(H_{\mathrm{p}} - H_{\mathrm{c}}\right)$ and $\left(F_{\mathrm{p}} - F_{\mathrm{c}}\right)$ are the differences in walk time, on-street wait time, off-street wait time, and taxi fare of the premium eTaxi compared to the conventional LPG taxi; α_{W}, α_{G}, α_{H} and α_{F} denote the corresponding coefficients to the attributes; and μ

denotes the model constant term. The attributes are actually the perceived values to a taxi customer for his/her decision of either taking a premium eTaxi or a conventional LPG taxi. Therefore, every taxi customer is assumed having the same perception of the utility function attributes, and subscript *i* is excluded in each attribute on the right-hand side of the equation for simplicity.

3.2 Watson and Westin Pooling Test

As the choice sets in the questionnaire survey were divided into two premium eTaxi vehicle types (standard and advanced premium types) and two taxi trip lengths (short and long trips), four individual models could be calibrated separately. The customers' selections were assumed to vary in different situations. Three combined models were hence proposed to validate this assumption, and the Waston and Westin Pooling Test (Watson and Westin, 1975) was used for each combination. The test involves the calculation of the log-likelihood ratio:

$$\mathrm{LR} = -2(L_{\mathrm{R}} - L_{\mathrm{U}}), \quad (3)$$

where L_{R} denotes the log-likelihood of the combined model, and L_{U} denotes the total likelihood of the corresponding individual models. When this ratio is larger than the threshold value stated in the chi-squared distribution at a selected level of significance, the null hypothesis of no intervention in segmentation (in trip length and/or vehicle type) is rejected. The degree of freedom is defined as the total number of explanatory variables in individual models minus the number of explanatory variables in the combined model minus.

3.3 Combined All-four-segment Model with Socio-demographic Variables

To reveal how the different trip characteristics, market segments, and the socio-demographic backgrounds of the respondents collectively affect the customers' selections, a combined all-four-segment model was developed and calibrated. It included the aforementioned socio-demographic variables. An additional explanatory variable of the desired improvement in taxi service quality was introduced. It indicates the difference between a respondent's rating of the current and desired taxi service qualities. Perceptibly, the less the existing service could meet a respondent's expectation, the more likely he/she would select a premium service. When the service level of the existing taxis falls short of customers' expectations, the premium service could be an attractive alternative option to the taxi customers. By adding these new explanatory variables, the revised utility function was obtained as follows.

$$V_i = U_i + \sum_r \left(\beta_S^r S^r \right) + \beta_D D_i + \sum_q \left(\beta_E^q E_i^q \right), \quad (4)$$

where $\sum_r \left(\beta_S^r S^r \right)$ is the effect of market segments (in different trip lengths and vehicle types) on taxi customers' selections; S^r denotes the dummy variable for market segment *r*; D_i denotes the desired improvement on taxi service quality; $\sum_q \left(\beta_E^q E_i^q \right)$ is the combined effect of socio-demographic factors of an individual taxi customer *i*, including the frequency of taking taxis, gender, age, occupation status, income, and car availability; E_i^q denotes the dummy variable for socio-demographic factor *q*; β_S^r, β_D, and β_E^q denote the corresponding model coefficients to the attributes. The revised utility function V_i replaces U_i in Equation (1) to develop the combined all-four-segment model.

4. RESULTS AND DISCUSSION

4.1 Binary Logistic Regression Model Results

A data analysis and statistical software package SPSS was used for model calibration, which relies on the maximum likelihood estimation method. Table 2 presents the results of the base model, which assumes that the customers have the same perceptions on the explanatory variables with different lengths of taxi trips, and different types of premium eTaxi vehicles.

Table 2. Coefficients and the associated t-statistics of the base model

Explanatory variable/constant term	Coefficient [*t*-statistic]
Walk time (min)	-0.067 [-5.2] *
On-street wait time (min)	-0.108 [-15.3] *
Off-street wait time (min)	-0.076 [-12.9] *
Taxi fare (HK$)	-0.004 [-1.6] ***
Constant	-0.190 [-1.3]

Note: * and *** represent that the parameters are significant at the 1% and 10% levels, respectively.

It is noted that the time-specific variables are all significant at the 1% level while the taxi fare is significant at the 10% level. The coefficients for the four trip characteristics are all negative, suggesting a clear preference for shorter walk time, shorter on-street/off-street wait times, and a lower taxi fare. The magnitudes of the coefficients also imply that the taxi customers preferred waiting off-street (e.g., at home or in another comfortable environment) to waiting on-street for vacant taxis. The constant term in the base model shows an insignificant negative value, which indicates a slight resistance to the proposed premium eTaxis. To conclude, all the coefficients have a logical sign for representing taxi customers' decisions and meet our expectations.

4.2 Market Segmentation Analysis

Table 3 presents the market segmentation analysis of the binary logistic regression models. It is noted that when the model was divided into two market segments based on trip lengths (as shown in the upper part), a significantly positive intercept could be obtained in the long trip model. The respondents were not opposing the premium eTaxis. In the short trip model, the constant term is negative and insignificant. It could be explained that when the trip was short, premium taxi service (e.g., a luxurious vehicle, and onboard amenities) might not be a primary concern for many taxi customers, but the prospect of getting a taxi quickly was the most important. Taxi customers were not in favor of spending longer times before boarding. In particular, waiting on streets was always less tolerated than waiting at more comfortable locations, whereas longer walk time was more acceptable on a long trip. All the coefficients in the sub-model for a long trip are larger than the counterparts for a short trip, meaning that customers were more willing to use premium services on a long trip with a higher quality vehicle type. It is because the onboard experience was deemed more important for a long journey. The intrinsic attractiveness of the premium service would be less pronounced on a short trip.

Table 3. Market segmentation analysis of the binary logistic regression models

Explanatory variable/constant term	Coefficient [*t*-statistic]			
	Market segment (1)		Market segment (2)	
	Premium eTaxis for a short trip		Premium eTaxis for a long trip	
Walk time (min)	-0.107 [-5.5] *		-0.042 [-2.3] **	
On-street wait time (min)	-0.127 [-12.2] *		-0.095 [-9.5] *	
Off-street wait time (min)	-0.082 [-9.4] *		-0.079 [-9.5] *	
Taxi fare (HK$)	-0.029 [-5.8] *		-0.017 [-5.2] *	
Constant	-0.276 [-1.3]		0.741 [3.5] *	
Explanatory variable/constant term	Market segment (1a)	Market segment (1b)	Market segment (2a)	Market segment (2b)
	Standard premium eTaxis for a short trip	Advanced premium eTaxis for a short trip	Standard premium eTaxis for a long trip	Advanced premium eTaxis for a long trip
Walk time (min)	-0.144 [-5.4] *	-0.092 [-3.0] *	-0.033 [-1.4]	-0.064 [-2.2] **
On-street wait time (min)	-0.135 [-8.6] *	-0.133 [-8.8] *	-0.080 [-5.4] *	-0.108 [-7.2] *
Off-street wait time (min)	-0.090 [-7.3] *	-0.075 [-6.0] *	-0.057 [-4.8] *	-0.101 [-8.0] *
Taxi fare (HK$)	-0.091 [-5.6] *	-0.038 [-2.5] **	-0.038 [-5.3] *	-0.024 [-3.4] *
Constant	0.218 [0.7]	-0.111 [-0.3]	0.873 [2.5] **	1.309 [3.7] *

Note: * and ** represent that the parameters are significant at the 1% and 5% levels, respectively.

To explore the effects of the two different types of eTaxi vehicles, four individual models were further calibrated and the results are provided in the lower part of Table 3. The results in the quadri-segmented models resonate with the bi-segmented models with subtle variations. For a short trip with the standard premium eTaxi (market segment 1a), the magnitudes of the negative coefficients of all trip attributes are smaller than those of the sub-model for a long trip with the same vehicle type (market segment 2a). This finding shows that every increase in pre-boarding times or the taxi fare would have a rather strong adverse impact on the taxi customers' decisions when a trip itself was short. For a short trip with the more luxurious Tesla Model S (market segment 1b), waiting on streets was the most unacceptable with the smallest coefficient (-0.133) among all time variables in this sub-model. The most eye-catching finding is that the constant terms of these two sub-models are insignificant. The respondents did not express a clear preference for traveling by premium eTaxis when the trip was short.

For a long trip with the standard premium eTaxi (market segment 2a), walk time, on-street/off-street wait time, and taxi fare became much less influential than those for a short trip with both types of eTaxi. Among all the time factors, on-street wait time remained the least tolerated factor (-0.080) while the off-street wait time was only mildly impactful (-0.057). A taxi fare increase for a long trip with the standard premium eTaxi became even less of a concern (-0.038) to the respondents compared with that for the corresponding short trip. The negative impact of walk time was minimal and insignificant. Notably, the constant term is positive, and its magnitude is much larger than that for a short trip. The result indicates that the respondents were more willing to travel by a premium taxi when the trip distance was long. For a long trip with the advanced premium eTaxi (market segment 2b), the negative impact of fare was further reduced to -0.024. Compared with that for a short trip with an advanced premium eTaxi (market segment 1b), walk time and on-street wait time for a long trip also became less influential, but the effect of the off-street wait time for a long trip increased to almost the same as that of on-street wait time. The constant term is the largest among all sub-models; the respondents were clearly willing to pay more for the more luxurious Tesla Model S for a long trip

To compare the individual models with their respective combined model, the Watson and Westin

Pooling Tests were performed. Table 4 summarizes the test results. The log-likelihood values of the bi-segmented models (The models for premium eTaxis for a short trip and a long trip) are -1673.4 and -1828.3 for a short trip and a long trip, respectively. Hence, the total likelihood of the corresponding individual models (L_U) is -3501.7. The log-likelihood of the combined model (L_R) is -3581.8. Therefore, the log-likelihood ratio is 160.2, which is significantly larger than the test statistic of 15.1 when the degree of freedom is 5 and the level of significance is 0.01. The null hypothesis that there is no intervention in the segmentation of trip length is rejected at the 1% level. By applying the same pooling test to the other two model combinations of quadri-segmented models, the likelihood ratios are 20.8 and 25.2 for model combinations 2 and 3, respectively. The values are also larger than the test statistic of 15.1 and the corresponding two null hypotheses are rejected at the 1% level. It is concluded that each market segment varies from the others and cannot be pooled, and hence one model is required for each of the different trip lengths and vehicle types.

Table 4. Results of the Watson and Wastin Pooling Tests

Combinations	Sub-models	L_R	L_U	LR	Conclusion*
Model combination (1)	Premium eTaxis for a short trip Premium eTaxis for a long trip	-3581.8	-3501.7	160.2	Reject
Model combination (2)	Standard premium eTaxis for a short trip Advanced premium eTaxis for a short trip	-1673.4	-1663.0	20.8	Reject
Model combination (3)	Standard premium eTaxis for a long trip Advanced premium eTaxis for a long trip	-1828.3	-1815.7	25.2	Reject

Note: * All the null hypotheses are significant at the 1% level.

4.3 The Combined All-four-segment Model with Socio-demographic Factors

A combined all-four-segment model was additionally calibrated to reveal how the different market segmentations, trip characteristics, and the socio-demographic backgrounds of the respondents have collectively affected the choices. The model results are tabulated in Table 5.

Table 5. Results of the combined all-four-segment model including the socio-demographic factors

Explanatory Variables	Group	Control	Coefficient [*t*-statistics]
Trip characteristics	Walk time (min)	-	-0.082 [-6.1] *
	On-street wait time (min)		-0.110 [-15.2] *
	Off-street wait time (min)		-0.080 [-13.1] *
	Taxi fare (HK$)		-0.035 [-7.6] *
Market segments	Advanced premium taxis for a short trip	Standard premium taxis for a short trip	0.222 [2.1] **
	Standard premium taxis for a long trip		0.842 [8.8] *
	Advanced premium taxis for a long trip		1.358 [8.6] *
Desired improvement on taxi service quality		-	0.069 [4.1] *
Monthly frequency of taking a taxi	1 – 6 times	Fewer than once	0.240 [3.8] *
	7 times or more		0.371 [3.9] *
Gender	Male	Female	-0.123 [-2.1] **
Age	Below 30 years	65 years or above	-0.237 [-1.4]
	30 – 64 years		-0.275 [-1.7] ***
Occupation status	Student	Full-time or part-time job	-0.220 [-2.8] *
	Others		-0.120 [-1.2]
Monthly income	HK$10,001 – 30,000	Below HK$10,001	0.323 [2.1] **
	HK$30,001 or above		0.623 [3.9] *

Car availability	Yes	No	0.009 [0.1]
Constant		-	-0.454 [-1.6] ***

Note: *, **, and *** represent that the parameters are significant at the 1%, 5%, and 10% levels, respectively.

It is noted that all the explanatory variables associated with the trip characteristics are significant and their coefficients are negative. The results are consistent with the base model results as shown in Table 2. For the variables for market segments, the model for standard premium eTaxis for a long trip shows a positive influence (0.842), while the respondents overwhelmingly (1.358) preferred the advanced premium eTaxis for a long trip for the extended time of enjoyment. The findings are consistent with the discussion in Section 4.2. For the newly introduced variable of the desired improvement on taxi service quality, its associated positive coefficient (0.069) implies that the less the existing service could meet a respondent's expectation, the more likely he/she would select a premium service.

The respondents' socio-demographic backgrounds contributed to their decision-making. The frequent taxi customers had a clear preference towards the premium option; their higher travel needs imply that they could afford to a more personalized mode and they attached greater value to quality services. Respondents who used taxis seven times or more in a month had the highest positive effect (0.371) to the utility among the three groups. The male respondents were slightly less likely (-0.123) to travel by a premium eTaxi. It could be explained that females are more sensitive to service quality, drivers' attitudes, and the level of comfort. Among different age groups of customers, service quality meant more to the elderly group. The respondents aged 65 or above were the most likely to select the premium option. As personal mobility generally decreases when age grows, the elderly population would prefer a better service quality and a higher comfort level. More specifically, the premium eTaxis serving in the dispatching mode introduces the possibility of waiting at home coupled with a short walking distance. This service is attractive to the elderly, especially for those with impaired mobility (Wong et al., 2019). Compared to the people with either a full-time or a part-time job, students and others (e.g., retirees and housewives) were less likely to select the premium option given their possibly lower disposable income or fewer travel needs. Regarding the income levels, as compared with a monthly income level below HK$10,001, respondents in the groups of HK$10,001-30,000 and HK$30,001 or above had a higher willingness to a premium eTaxi. It validates the model assumptions of Wong et al. (2008). Car availability had an insignificant positive value, which implies that people with a private car had a slight tendency to use a premium eTaxi. The constant term is modest (-0.454), which means that the proposed model can well depict the travel behavior of taxi customers with limited uncaptured factors.

4.4 Recommendations and Policy Implications

The proposed dispatching premium eTaxi operational design is potentially appealing to taxi customers. Should the government decide to put forward a scheme of electrifying the existing taxi fleets, a variety of concerns must be addressed. According to the model results, long wait times significantly influence customers' selections. The premium eTaxis should aim to improve dispatching efficiency so as to reduce off-street wait time. To achieve this, a reasonably large fleet size should be maintained so that the driving distance of dispatching taxis can be kept to a minimum. A centralized dispatching platform should also be formed to handle the orders for premium eTaxis systematically. Furthermore, sufficient charging stations and fast-charge technologies are imperative in sustaining the operational efficiency of the eTaxi fleet (Han et al., 2016; Tu et al., 2016). It is suggested to improve the existing charging facilities at car parks, and consider providing fast-chargers for eTaxis at taxi stands.

Other than the time-specific attributes, taxi fare poses an important factor in the choice model that significantly influences the customers' travel decisions. To ensure sufficient customers for the premium service, its fare structure should be established carefully. In addition, the government should aim to ensure fairness and broader inclusion in the deployment of premium eTaxis. As the model results have suggested, the elderly group would choose a higher-quality service that can accommodate their special travel needs. Dedicated taxi fare plans can be considered to further improve the mobility of the elderly (Wong et al., 2019).

For the vehicle type of premium eTaxis, the more luxurious Tesla Model S is recommended. It outweighs BYD e6 and attracts more ridership for both short and long trips as presented in the combined all-four-segment model result. To simulate a broader use of eTaxis, the government should consider offering the same amount of subsidies as in 2012 (up to HK$300,000) to replace a proportion of LPG taxis. The purchase price of a typical Toyota Crown LPG taxi is about HK$250,000 (Toyota Hong Kong, 2017), and that of a typical Tesla Model S is HK$560,000 (Tesla Inc., 2017). With the aforementioned financial support, an advanced premium eTaxi will cost only HK$260,000, which is considered affordable for taxi operators.

Regarding the service quality of taxi drivers, the government should clearly define the requirements of premium services regarding driver’s professionalism and courteousness. An additional training and a dedicated permit are mandatory for taxi drivers operating a premium eTaxi. In addition, a continuous monitoring mechanism should also be established to maintain service quality.

This proposal of introducing premium eTaxis intends to bring government input and customers’ willingness together to contribute to the environment. In return, it not only brings environmental benefits but also offers the customers higher quality services, which also justify their monetary input. Given that the rate of NOx emissions of LPG taxis ranges from 0.06 to 0.11 g/km when traveling at a speed between 30 and 70 km/h (Ning and Chan, 2007), the CO2-equivalent emissions per kilometer traveled of LPG taxis and eTaxis are 121 g and 107 g respectively (Leung et al., 2010; CLP, 2018), the annual driving mileage of all taxis is about 2399 million km (Transport Advisory Committee, 2014), and the unit fuel consumption of the LPG taxis is 0.111 L/km, it can be calculated that about 14–26 tons of NOx and 3359 tons of CO2-equivalent emissions can be reduced, and 26.6 million liters of LPG can be saved for every 10% of LPG taxis (about 1816 taxis) converted to eTaxis (Yang et al., 2018). Increasing the percentage of eTaxis in the existing taxi fleet is an essential element of public transport policy for Hong Kong to meet its emission target of reducing its overall carbon footprint by 70% of the 2005 level by the end of 2030 (Environment Bureau, 2017).

5. CONCLUSION

Conventional LPG taxis in Hong Kong are one of the main contributors to roadside emissions as they operate on the streets 24 hours a day with a long daily driving mileage, and they also have an extremely poor service reputation. To improve taxi service levels while reducing their roadside emissions, we proposed a premium service operated by eTaxis in the dispatching mode. Hong Kong was adopted as a case study to find out the customers' acceptance of premium eTaxis. In this study, 1410 Hong Kong taxi customers were interviewed, and their taxi riding behaviors and attitudes towards electric vehicles and premium taxis were collected. A stated preference survey was included to capture the factors that may influence their selections in a differentiated taxi market with premium eTaxis and conventional LPG taxis. Furthermore, different lengths of taxi trips and types of electric vehicles (i.e., the standard premium and the advanced premium eTaxis) have been included in the questionnaire design to identify customers' preferences. Binary logistic regression models were calibrated to determine the level of impact each factor had on customers' choice behavior in different market segments.

The model results show that customers were more willing to use a premium service on a longer taxi trip and a more luxurious vehicle option can attract more demand. Customers were less price-sensitive on a long trip and were willing to pay more for better services. The walk time, on-street and off-street wait times, and taxi fare were found significant to influence customers' selections. Customers generally preferred waiting off-street than on-street, which is a benefit the proposed dispatching operational design can offer. Walk time to the pick-up location was rather influential to the customers on a short trip while it was better tolerated on a long trip. Through the market segmentation analysis, this study confirmed the existence of finer niches among taxi customers and identified their preferences.

To encourage more people to ride the greener taxis, a reasonably large fleet size of premium eTaxis should be maintained so that the driving distance of dispatching taxis can be kept to a minimum and the off-street wait time for a taxi could be reduced. The existing charging facilities should be improved to mitigate taxi drivers' concerns of excessive recharging time, reduction of operational hours, and insufficient driving range. The fare structure of premium service should be established at a reasonable level to ensure sufficient customers. Additional financial support to the elderly of taking premium eTaxis is suggested to accommodate their special travel needs. The more luxurious Tesla Model S is recommended for providing the premium eTaxi service and direct subsidies from the government to the taxi operators should be considered to encourage more extensive use of premium eTaxis. The service requirements of premium eTaxis should be clearly defined and a continuous monitoring mechanism should be established to uphold the high-quality service.

A number of areas need to be further explored in future studies: (1) A 10-min charging by using the latest fast-charge technology can provide sufficient power for traveling up to 100 km. The drivers need to wait and recharge their premium eTaxis at taxi stands with fast-chargers between order assignments. Therefore, the number and location of the taxi stands should be allocated strategically to minimize the required access time of taxi drivers. (2) The fare structure of premium eTaxis may affect the respective off-street wait time of taxi customers. If the additional fare for the premium service is low, more customers will choose the premium eTaxis and that leads to a longer wait time, vice versa. A reasonable fare structure to strike a balance between demand and supply is essential and important to the success of the premium eTaxi service. To address these problems, a network-based simulation model is, therefore, recommended to conduct sensitivity tests with different fleet sizes and fare structures and different settings of taxi stands for recharging. The results will provide suggestions to the governments for introducing the proposed premium eTaxis in Hong Kong and in some other international cities that have a similar taxi market.

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References

Agresti, A., 2006. An Introduction to Categorical Data Analysis. John Wiley & Sons, Inc., New Jersey, United States.

Bonges III, H.A., Lusk, A.C., 2016. Addressing electric vehicle (EV) sales and range anxiety through parking layout, policy, and regulation. Transportation Research Part A 83, 63–73.

Buekers, J., van Holderbeke, M., Bierkens, J., Panis, L., 2014. Health and environmental benefits related to electric vehicle introduction in EU countries. Transportation Research Part D 33, 26–38.

Cavallaro, F., Danielis, R., Nocera, S., Rotaris, L., 2018. Should BEVs be subsidized or taxed? A European perspective based on the economic value of CO2 emissions. Transportation Research Part D 64, 70–89.

Clean Air Network of Hong Kong, 2017. Annual Air Quality Review. http://www.hongkongcan.org/hk/wp-content/uploads/2017/01/Clean-Air-Network-2016-Annual-Air-Quality-Review-Jan-2017.pdf

CLP Group, 2018. CLP Group Sustainability Report. CLP Group, Hong Kong.

Environment Bureau, 2017. Hong Kong's Climate Action Plan 2030+. The Hong Kong SAR Government, Hong Kong.

Environmental Protection Department, 2015. 12-month Interim Reports on Electric Taxi Trials. The Hong Kong SAR Government, Hong Kong.

Environmental Protection Department, 2017. Greenhouse Gas Emissions and Carbon Intensity in Hong Kong. The Hong Kong SAR Government, Hong Kong.

Gacias, B., Meunier, F., 2015. Design and operation for an electric taxi fleet. OR Spectrum 37, 171–104.

Gawron, J.H., Keoleian, G.A., De Kleine, R.D., Wallington, T.J., Kim, H.C., 2019. Deep decarbonization from electrified autonomous taxi fleets: Life cycle assessment and case study in Austin, TX. Transportation Research Part D 73, 130–141.

Hagman, J., Langbroek, J.H.M., 2018. Conditions for electric vehicle taxi: A case study in the greater Stockholm region. Transportation Research Board 97th Annual Meeting, Washington D.C., United States, 7–11 January 2018.

Hao, H., Ou, X., Du, J., Wang, H., Ouyang, M., 2014. China's electric vehicle subsidy scheme: Rationale and impacts. Energy Policy 73, 722–732.

Han, D., Ahn, Y., Park, S., Yeo, H., 2016. Trajectory-interception based method for electric vehicle taxi charging station problem with real taxi data. International Journal of Sustainable Transportation 10(8), 671–682.

Kim, J., Lee, S., Kim, K.S., 2017. A study on the activation plan of electric taxi in Seoul. Journal of Cleaner Production 146, 83–93.

Lau, J., Hung, W.T., Cheung, C.S., 2012. Observation of increases in emission from modern vehicles over time in Hong Kong using remote sensing. Environmental Pollution 163, 14–23.

Legislative Council, 2016. Discussion of the Transport Strategy Study – Role and Positioning Review on 21 June 2016. The Hong Kong SAR Government, Hong Kong.

Leung, M.K.H., Leung, D.Y.C., Chan, A.H.S., Cheng, D.M., Shek, T., Lam, G.C.K., Cheng, S.W.K., Koo, B.C.P., Yun, D., 2010. Carbon Audit Toolkit for Small and Medium Enterprises in Hong Kong. The University of Hong Kong, Hong Kong.

Li, Y., Zhan, C., de Jong, M., Lukszo, Z., 2016. Business innovation and government regulation for the promotion of electric vehicle use: Lessons from Shenzhen, China. Journal of Cleaner Production 134, 371–383.

Liu, J., Santos, G., 2015. Decarbonising the road transport sector: Breakeven point and consequent potential consumers' behaviour for the US case. International Journal of Sustainable Transportation 9(3), 159–175.

Meisel, S., Merfeld, T., 2018. Economic incentives for the adoption of electric vehicles: A classification and review of e-vehicle services. Transportation Research Part D 65, 264–287.

Netherlands Enterprise Agency, 2015. Electromobility in the Netherlands: Highlights 2014. Amsterdam, Netherlands.

New York City Taxi & Limousine Commission, 2013. Take Charge: A Roadmap to Electric New York City Taxis. New York, United States.

Nie, Y., 2017. How can the taxi industry survive the tide of ridesourcing? Evidence from Shenzhen, China. Transportation Research Part C 79, 242–256.

Ning, Z., Chan T.L., 2007. On-road remote sensing of liquefied petroleum gas (LPG) vehicle emissions measurement and emission factors estimation. Atmospheric Environment 41(39) 9099–9110.

Park, S.O., Yoon, S.M., 2017. The effects of taxpayer's environmental morale on the willingness to pay environmental tax for sustainable environment. International Journal of Applied Engineering Research 12(24), 14054–14063.

Rayle, L., Dai, D., Chan, N., Cervero, R., Shaheen, S., 2016. Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. Transport Policy 45, 168–178.

Steinhilber, S., Wells, P., Thankappan, S., 2013. Socio-technical inertia: Understanding the barriers to electric vehicles. Energy Policy 60, 531–539.

Shao, S., Tian, Z., Fan, M., 2018. Do the rich have stronger willingness to pay for environmental protection? New evidence from a survey in China. World Development 105, 83–94.

Teixeira, A.C.R., Sodré, J.R., 2018. Impacts of replacement of engine powered vehicles by electric vehicles on energy consumption and CO_2 emissions. Transportation Research Part D 59, 375–384.

Tesla Inc., 2017. Models and Prices. https://www.tesla.com/en_HK/models.

Toyota Hong Kong, 2017. Toyota Commercial Vehicle Price List 2017. http://www.toyota.com.hk/Toyota/media/General/2017%20Price%20List/20170317-Toyota-Commerical-Vehicle_Price-List.pdf.

Transport Advisory Committee, 2014. Report on Study of Road Traffic Congestion in Hong Kong. The Transport and Housing Bureau, The Hong Kong SAR Government, Hong Kong.

Transport Advisory Committee, 2017. Quarterly Report of the Transport Complaints Unit. The Transport and Housing Bureau, The Hong Kong SAR Government, Hong Kong.

Transport Department, 2017. Annual Transport Digest 2017. The Hong Kong SAR Government, Hong Kong.

Tu, W., Li, Q., Fang, Z., Shaw, S., Zhou, B., Chang, X., 2016. Optimizing the locations of electric taxi charging stations: A spatial–temporal demand coverage approach. Transportation Research Part C 65, 172–189.

Wang, Y., Ding, W., Huang, L., Wei, Z., Liu, H., Stankovic, J.A., 2018. Toward urban electric taxi systems in smart cities: The battery swapping challenge. IEEE Transaction on Vehicular Technology 67(3), 1946–1960.

Watson, P.L., Westin, R.B., 1975. Transferability of disaggregate mode choice models. Regional Science and Urban Economics 5(2), 227–249.

Wong, K.I., Wong, S.C., Yang, H., Wu, J.H., 2008. Modeling urban taxi services with multiple user classes and vehicle modes. Transportation Research Part B 42, 985–1007.

Wong, R.C.P., Szeto, W.Y., 2018. An alternative methodology for evaluating the service quality of urban taxis. Transport Policy 69, 132–140.

Wong, R.C.P., Szeto, W.Y., Wong, S.C., 2015. Behavior of taxi customers in hailing vacant taxis: A nested logit model for policy analysis. Journal of Advanced Transportation 49, 867–883.

Wong, R.C.P., Szeto, W.Y., Wong, S.C., Yang, H., 2014. Modelling multi-period customer-searching behaviour of taxi drivers. Transportmetrica B 2, 40–59.

Wong, R.C.P., Yang, L., Szeto, W.Y., Li, Y.C., Wong, S.C., 2019. The effects of accessible taxi service and taxi fare subsidy scheme on elderly’s willingness-to-travel. Transport Policy, under review.

Yang, J., Dong, J., Lin, Z., Hu, L., 2016. Predicting market potential and environmental benefits of deploying electric taxis in Nanjing, China. Transportation Research Part D 49, 68–81.

Yang, L., Wang, Y., Han, S., Liu, Y., 2019. Urban transport carbon dioxide (CO2) emissions by commuters in rapidly developing cities: The comparative study of Beijing and Xi’an in China. Transportation Research Part D 68, 65-83.

Yang, W.H., Wong, R.C.P., Szeto, W.Y., 2018. Modeling the acceptance of taxi owners and drivers to operate premium electric taxis: Policy insights into improving taxi service quality and reducing air pollution. Transportation Research Part A 118, 581–593.

Zhang, S., Zhao, J., 2018. Low-carbon futures for Shenzhen's urban passenger transport: A human-based approach. Transportation Research Part D 62, 236–255.

Zou, Y., Wei, S., Sun, F.H.X., Shiao, Y., 2016. Large-scale deployment of electric taxis in Beijing: A real-world analysis. Energy 100, 25–39.

Appendix – Sample Questionnaire of Standard Premium eTaxis

Personal particulars and travel patterns of taking taxis [please tick as appropriate]

1. How many times did you take taxis in the past three months?
☐Seldom ☐1–3 ☐4–6 ☐7–9 ☐10 or above

2. Gender:
☐Male ☐Female

3. Age:
☐Below 18 ☐18–29 ☐30–49 ☐50–64 ☐65 or above

4. Occupation:
☐Full-time job ☐Part-time job ☐Student ☐Housewife ☐Others

5. Household monthly income:
☐Below $10,001 ☐$10,001–20,000 ☐$20,001–30,000
☐$30,001–40,000 ☐$40,001 or above

6. Car availability for family use:
☐No ☐1 ☐2 or above

7. Main trip purpose(s) of taking taxis: (*allow multiple answers*)
☐Going to work/school ☐Going back from work/school
☐Shopping and entertainment ☐Visiting friends and relatives
☐Social activities ☐Dining ☐Medical purpose
☐Others (Please specify:___________________)

8. Main reason(s) for taking taxis: (*allow multiple answers*)
☐Convenience ☐Level of comfort ☐Adverse weather
☐In a rush ☐Not familiar with the local roads
☐Carrying heavy baggage ☐No other suitable public transport mode to destination
☐Others (Please specify:___________________)

9. Most frequent way(s) of hailing taxis: (*allow multiple answers*)
☐Street hailing ☐Waiting at taxi stands
☐Taxi dispatching (☐ordered by phone / ☐ ordered by smartphone apps)

10. Most frequent period(s) of taking taxis: (*allow multiple answers*)
☐Morning peak (6am to 10am) ☐Noon inter-peak (10am to 5pm)
☐Evening peak (5pm to 9pm) ☐Mid-night inter-peak (9pm to 6am)

11. Do you agree that there is a necessity to replace conventional LPG taxis with greener electric taxis to improve roadside air quality?
☐Yes (☐all taxis / ☐only old and polluting taxis) ☐No

12. How much would you like to pay for greener electric taxis?
☐None ☐1–10% ☐11–20% ☐21–30% ☐More than 30%

13. Please rate the current taxi service quality: (1 for very dissatisfied; and 10 for very satisfied)
Dissatisfied ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Satisfied

14. Please rate the desired taxi service quality: (1 for very dissatisfied; and 10 for very satisfied)
Dissatisfied ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Satisfied

15. How much would you like to pay for better services to achieve the desired level?
☐None ☐1–10% ☐11–20% ☐21–30% ☐More than 30%

Travel decisions between an LPG taxi and a premium electric taxi [please tick as appropriate]

Assume that a proportion of LPG taxis will be converted to electric taxis that provide premium services as shown below:

Vehicle class	BYD e6
Driver services	Well-trained and attentive drivers, luggage handling, and door-opening service
Additional services	Onboard amenities such as audio/video equipment, wireless internet connection, chargers, and multiple payment channels (e.g., credit card and e-payments)

Based on the above premium taxi service standard, which is the most preferred choice in each of the following four independent scenarios?

1. If you are going to make a short trip for about 5 km by taxi (e.g., from Central to Causeway Bay)

Game 1	**Taxi calling for a premium electric taxi** Waiting at a comfortable location (e.g., at home, in office, or in a shopping mall) for 12 minutes, and walking to a pick-up point for 4 minutes. Travel fare is $55.	☐
	Hailing on-street or waiting at a taxi stand for an LPG taxi Walking to the roadside or a taxi stand for 5 minutes, and waiting for 15 minutes. Travel fare is $40.	☐

Game 2	**Taxi calling for a premium electric taxi** Waiting at a comfortable location (e.g., at home, in office, or in a shopping mall) for 24 minutes, and walking to a pick-up point for 2 minutes. Travel fare is $45.	☐
	Hailing on-street or waiting at a taxi stand for an LPG taxi Walking to the roadside or a taxi stand for 7 minutes, and waiting for 10 minutes. Travel fare is $40.	☐

2. If you are going to make a long trip for about 15 km by taxi (e.g., from Central to Airport)

Game 3	**Taxi calling for a premium electric taxi** Waiting at a comfortable location (e.g., at home, in office, or in a shopping mall) for 18 minutes, and walking to a pick-up point for 4 minutes. Travel fare is $120.	☐
	Hailing on-street or waiting at a taxi stand for an LPG taxi Walking to the roadside or a taxi stand for 5 minutes, and waiting for 10 minutes. Travel fare is $100.	☐

Game 4	**Taxi calling for a premium electric taxi** Waiting at a comfortable location (e.g., at home, in office, or in a shopping mall) for 12 minutes, and walking to a pick-up point for 6 minutes. Travel fare is $130.	☐
	Hailing on-street or waiting at a taxi stand for an LPG taxi Walking to the roadside or a taxi stand for 9 minutes, and waiting for 5 minutes. Travel fare is $100.	☐