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Freeway drivers' willingness to pay for an on board unit under an electronic toll collection system

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ABSTRACT

Electronic toll collection (ETC) systems have been put into practice in one or two channels at toll plazas on Taiwan's freeways since 2006. The utilisation of the ETC system has been flat due to the extra cost of installing the on board unit (OBU) that is used in the system. To increase the utilisation rate of the ETC system, it is crucial to understand the real price that drivers are willing to pay. Therefore, this study investigates freeway drivers' willingness to pay a value for an OBU. A stated preference experiment is designed to obtain the willingness to pay at three different levels of use. To avoid the estimation bias due to a large percentage with a zero willingness to pay, a spike model is used. Different markets are segmented to examine their willingness to pay for an OBU. The estimation results show that the willingness to pay for an OBU is NT$727/unit[1] for short distance drivers, NT$830 for medium distance drivers, and NT$1308/unit for long distance drivers.

1. Introduction

The freeway electronic toll collection (ETC) system is a non-contact freeway toll collection system. Due to its low cost, among other benefits, compared to a manual toll collection (MTC) system, more and more countries have implemented an ETC system (e.g., FasTrak, E-Zpass, I-Pass in the US; Japanese ETC system; Singapore's ERP system; Australia's Melbourne City Link ETC System). Compared to a traditional MTC system, an ETC system does not require the traffic to stop for toll collection; therefore, the shortened toll collection time not only increases toll collection capacity but also decreases air pollution and carbon emissions, thereby achieving environmental protection objectives.

In Taiwan, the government signed the ETC's BOT contract with Far Eastern Electronic Toll Collection Co, Ltd. (FETC) in 2003. In order to transit the toll system on freeways from frequency-based to distance-based, there are two phases in practice. From 2006 till 2012, FETC operated one or two ETC lanes among other manual toll collection lanes in all toll plazas on the freeways. After 2013, all toll plazas will be removed and distance-based ETC system will be fully implemented (no more frequency-based tolling). However, one threshold that FETC has to meet to move to the second phase is the ETC utilisation rate shall reach 65%. If it fails to cross the threshold, FETC has to face a serious penalty of 17,000 USD per day and the second phase will be delayed. Since the current rate is less than 50% (2012), FETC is eager to do whatever it can to increase the utilisation rate.

Under the current freeway ETC system, the major cost for drivers is derived from purchasing the on board unit (OBU), which is a required sensing device for toll collection when the vehicles approach the toll stations. FETC does not provide driv-

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[1] *Note*: 30.04NT$ was equivalent to $1 USD (October, 2011).

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Table 1
Taiwan's OBU installation and freeway ETC operation status. *Source*: Taiwan Area Freeway Department (2011).

Item	2006	2007	2008	2009	2010	2011 January–November
OBU installation (unit)	247,113	166,255	288,997	252,261	163,323	135,430
Number of toll pass (in 10,000)	54,554	52,666	50,028	51,757	54,403	47,336
Number of ETC pass	5382	10,057	14,128	17,567	21,178	22,505
ETC pass percentage (%)	9.87	19.00	28.15	33.65	38.61	41.65

Note: (ETC pass percentage) = /(ETC total number of pass (Manual + ETC)) (Number of ETC pass).

ers an OBU for free. Drivers must pay for the device. Until 2011, the average utilisation rate of the ETC system was only 41.65% (Taiwan Area National Freeway Bureau, 2011), which was far from the government's goal of full-scale implementation by the end of 2012. The drivers' complaint that the OBU sales price was too high and the news that the Ministry of Transportation and Communication (MOTC) demanded the FETC to reduce the OBU selling price show that the public is not willing to accept the current OBU installation costs. Therefore, the main problem for the low utilisation rate is because of the price of OBU is too high. Understanding the drivers' willingness to pay (WTP) for an OBU is an important topic. Because the OBU possesses the characteristics of a non-market good, we used the contingent valuation method (CVM) to construct the scenario prices for the drivers' WTP.

Because the price of a respondent's WTP is likely to be zero, past research (Kriström, 1997; McCartney, 2006; Hanley et al., 2009; Jou and Wang, 2012; Jou et al., 2011b, 2012b; Jou and Chen, 2012a) often uses a spike model to overcome this problem and to avoid model estimation error. In this study, spike model is also applied based on two main reasons. Firstly, the method is recognised as an appropriate one when there is a great portion of unwillingness to pay. In our study, around 25% of drivers were unwilling to pay which justifies the use of spike model. Secondly, it is crucial to raise the utilisation rate of ETC system due to the contract requirement. Since the low utilisation rate is because the price of OBU is too high, it is meaningful to investigate the WTP for OBU by using spike model. Hu's (2006) research suggests that the standard deviation of a single variable model is smaller than that of a spike multi-variable model. If the goal is to achieve more accurate WTP estimates, the single variable model is more appropriate. However, the spike multi-variable model can address the impact of the variables on the WTP and the relationships between variables, as well as to help provide advice concerning OBU pricing. Thus, this research uses both single variable and multi-variable models.

Finally, since around 50% of the freeway trips are the short distance trips (Taiwan Area National Freeway Bureau, 2010), no toll has to be paid by these drivers. It is reasonable to assume their WTP for OBU is lower than longer distance trips. Therefore, this research segments the trips by dividing the sample into three segments[2], short distance (below 50 km), medium distance (51–150 km), and long distance (above 151 km), to understand the influence of distance on the willingness to pay for an OBU.

The rest of this paper is organised as follows. Firstly, a brief literature review is presented in Section 2, followed by a brief introduction to the spike model. Section 4 presents the questionnaire design and survey along with some descriptive statistics. Model estimation results along with some policy implications are given in Section 5. Finally, concluding remarks and suggestions for future studies are presented.

2. Literature review

2.1. Taiwan's freeway ETC system implementation status

Taiwan's freeway ETC project was implemented according to the build–operate–transfer (BOT) model. The Far East Electronic Toll Collection Co., Ltd. (FETC) won the open bid in August 2003 and completed the system configuration in 2005. The system was officially launched on February 10th, 2006. According to the statistics of the Taiwan Area Freeway Bureau of the Ministry of Transportation and Communication, the overall ETC utilisation rate in 2006 was only 9.87% (Table 1). Although the number of OBU installations and the utilisation of ETC have increased every year, the utilisation rate is still far behind the government's goal of full-scale implementation by the end of 2012. This lag is partially due to the high OBU sales price. At the beginning of ETC operation in 2006, each OBU was sold at NT$1300/unit. During the promotion between January 9th, 2006 and April 9th, 2006, 200,000 units were sold at NT$680/unit. Between January 1st, 2009 and February 2nd, 2009, each OBU unit was sold at NT$1000 (including an NT$300 credit). Afterwards, each unit was sold at NT$1199 up until October 2010.

Because the ETC system has caused much controversy since its launch, the government and public opinion have raised questions concerning the OBU price. This controversy shows that drivers are reserved about the OBU installation. Although it has been over 5 years since the launch, there are not many additional drivers that feel positively about the OBU installations. This result not only directly hinders the effect of MOTC's current policies and the implementation of future policies, but it also indirectly impacts the development of ETC related industries. The departments involved should carefully consider this issue.

[2] The definition of categories of travel distance has been commonly used in Taiwan, both in academic research or governmental reports. Please refer to Taiwan Area National Freeway Bureau (2010).

2.2. Freeway ETC system study

Studies of the ETC system rarely investigate the willingness of drivers to pay for the OBU but instead focus on the factors that impact the usage of the ETC system. Jou et al. (2011) explored the media's impact on drivers' freeway usage. Lee et al. (2008) discussed the design and execution of a vehicle positioning system (VPS)-based ETC system. The study shows that the traditional ETC system is a dedicated short-range communications (DSRC)-based system; however, in recent years, extensive regionally integrated multilane free flow (MLFF) toll systems are gradually replacing the DSRC-based ETC systems. These transformed ETC systems use VPS technology, a location-based service that begins collecting fees only after the vehicle enters the toll area; this technology is considered to be the solution for an extensive regionally integrated toll system because compared to a DSRC based ETC system, it uses a completely different method for making electronic payments and therefore makes toll collections easier. Finally, the research uses the VPS-based ETC system as the discussion subject and analyses its strengths and weaknesses compared to a traditional ETC system.

In addition, Levinson and Chang (2003) use the maximising social welfare approach. Through statistical estimation, they discovered that time delay, price level, and the fixed cost of the OBU, etc., affected the drivers' use of the ETC system. Their analysis discovered that the fixed cost of the OBU is the most important item. Once a driver installs the OBU, the future cost of the ETC usage will quickly be reduced. The social welfare level is relevant to the ratio of the ETC usage, including time delay, gasoline consumption, electronic toll collection cost, and the social cost of air pollution. The study also holds that too many ETC lanes will cause extra time delays for the drivers that do not have an OBU installed. Ogden (2001) argued that because each ETC system is unique and is capable of collecting data on driving behaviours relevant to issues of personal privacy, if these data are collected and analysed, personal privacy could be compromised. Similarly, Riley (2008) also believed that one of the major barriers to drivers' adoption of the ETC system is the possible privacy exposure. His research discovered that the ETC utilisation rate in the California Bay Area (FasTrak) is lower than that of other similar areas (Delaware, Florida, Illinois, New York, and New Jersey). The research notes that consumers' privacy concerns outweigh the convenience of the ETC system and thereby reduces its utilisation.

Holguín-Veras and Preziosi (2011) noted that metropolitan traffic congestion is often a pressing issue facing decision makers. The ETC system is widely considered to be the best system to eliminate traffic congestion and the inconvenience of a manual toll system. The research targets New York City small passenger car drivers and explores the factors that affect their use of the ETC system. The results show that time savings, economic benefits from the use of the ETC system (the difference of toll cost between the ETC system and the MTC system and the driver's sensitivity to discounts with the ETC system), and other socioeconomic variables (frequency of ETC usage, number of possessed vehicles, education level, age, income, etc.) are directly related to the ETC system utilisation.

2.3. Literature related to the willingness to pay spike model

The contingent valuation method (CVM) is used in many fields to measure the value of non-market goods (Barreiro et al., 2005; Yoo et al., 2006). Some studies use logit or probit models to estimate the WTP (Jou and Chen, 2012a; Jou et al., 2012b), which can produce model estimation errors if there are too many zero WTP responses. For this reason, many studies use the spike model, which was initially proposed by Kriström (1997), to overcome this problem. The study shows that in most zero WTP samples, the price estimation from the spike model is more reasonable. Jou et al. (2011) explore consumers' willingness to purchase a business class ticket in the future and their WTP for business class tickets as well as additional business class services.

McCartney (2006) studied whether the erection of a wind turbine tower at Australia's Jurien Bay Marine Park would affect the view of the ocean and beach. The research uses the double-bound approach of CVM to design the questionnaire for price collections. Hanley et al. (2009) discussed the British public's WTP for changing the landscape of the Lake District Park and Trossachs Park using compensating variation and equilibriating variation as a way to measure social welfare. WTP was introduced through payment cards. Those that remained neutral were not asked about their WTP. Spike models and logit models were used to model the parameter estimation.

Jou and Wang (2012) set the research target as the WTP in Taiwan for speeding fines, running a red light, right turn on red, and driving under the influence. The research model uses the logit bivariate probability model and the spike model, which is able to handle 0 WTP to reduce the error caused by a high percentage of 0 WTP responses. In Jou et al. (2011b), the research target is the remaining time (in seconds) of a red light that drivers are willing to stop and wait. The research designs a questionnaire, collects information based on a CVM, and then uses a spike model to build a model to calculate the remaining time of a red light that drivers are willing to wait.

3. Model theory

Previous reviews of domestic ETC research show that the research on the WTP for freeway tolls is scarce, particularly on the willingness to pay for an OBU. In addition to its convenience, the CVM estimation of the respondents' WTP for non-market goods is more accurate. Therefore, the questionnaire in this research follows the CVM approach to design the WTP scenarios. In terms of the model estimation, when samples contain too many zero WTP responses, traditional model estimation could result in a negative WTP, causing estimation errors. The traditional CVM approach, when analysed using bivariate probability models (such as logit and probit bivariate models), could produce estimation error if the percentage of 0 WTP responses is too high. Therefore, in this scenario, the spike model is more appropriate for WTP estimation (Saz-Salazar and Garcia-Menendez, 2001). In addition, this research uses single variable and multi-variable models to take into account the accuracy of the estimated WTP (Hu, 2006) as well as to understand the impacts of the other variables. The following is a description of the spike model.

The spike model proposed by Kriström (1997) is based on random utility theory. The model allows 0 WTP in its estimation and is able to avoid the anomaly of a negative WTP. The questionnaire used in this research follows the CVM approach to data collection and explores the respondents' WTP. The random utility function that models individual decision making is expressed as follows:

$$U(Y,X,Q) = V(Y,X,Q) + \varepsilon_0 \tag{1}$$

where Y is the personal disposable income, X is the driver's socio-economic variables, Q is the travel preference related variables, and ε is a utility function random item that is independently and identically distributed (iid), with 0 as the expected average value. When drivers accept the hypothetical market price (A_1) because the hypothetical derivative market utility (scenario 1) is higher than the original utility (scenario 0), the individual utility function can be rewritten as follows:

$$V_1(Y - A_1, X, Q_1) + \varepsilon_1 \geqslant V_0(Y, X, Q_0) + \varepsilon_0 \tag{2}$$

ε_0 and ε_1 are independently and identically distributed with a 0 expected value. Thus, the probability function for the drivers accepting (A_1) can be derived from expression (2) to expression (3).

$$\begin{aligned} &V_1(Y - A_1, X, Q_1) - V_0(Y, X, Q_0) \geqslant \varepsilon_0 - \varepsilon_1 \\ &\Pr(\text{Yes}) = \Pr(\Delta V(\cdot) \geqslant \varepsilon) = F_\varepsilon(\Delta V(\cdot)) \end{aligned} \tag{3}$$

Because WTP represents the maximum amount that the drivers accept, when the scenario provides a price lower than the WTP (WTP $\geqslant A_1$), the drivers always accept the price. Therefore, the drivers' acceptance probability function can be expressed as follows:

$$\Pr(\text{Yes}) = \Pr(\text{WTP} \geqslant A_1) = 1 - F_{\text{WTP}}(A_1) = F_\varepsilon(\Delta V(\cdot)) \tag{4}$$

$F_{\text{WTP}}(A_1)$ represents the cumulative distribution function and is shown in expression (5):

$$F_{\text{WTP}}(A_1) = \begin{cases} F_{\text{WTP}}(A_1), & \textit{if}\ A_1 \leqslant 0 \\ P, & \textit{if}\ A_1 = 0 \\ 0, & \textit{if}\ A_1 \geqslant 0 \end{cases} \tag{5}$$

P belongs to (0,1), and F_{WTP} (A_1) is a continuous increasing function. If F_{WTP} (A_1 = 0) = P and lim $A_1 \to \infty$, then F_{WTP} (∞) = 1.

The estimated value of WTP E(WTP) can then be expressed as follows:

$$E(\text{WTP}) == \int_0^\infty (F_\varepsilon(\Delta V(\cdot)))dA_1 - \int_{-\infty}^0 (1 - F_\varepsilon(\Delta V(\cdot)))dA_1 \tag{6}$$

Therefore, the parameter estimation of the spike model is calculated using MLE, as shown in expression (7).

$$\ln L = \sum_i^N M_i W_i \ln(1 - F_{\text{WTP}}(A_1)) + \sum_i^N M_i(1 - W_i)\ln(F_{\text{WTP}}(A_1) - F_{\text{WTP}}(0)) + \sum_i^N (1 - M_i)\ln(F_{\text{WTP}}(0)) \tag{7}$$

M represents the existence of the WTP (WTP > 0), and W represents a WTP that is greater than the acceptance or the designed acceptance price (A_1). These variables are defined as follows:

$$M = \begin{cases} 1, & \text{WTP} \leqslant 0 \\ 0, & \text{other} \end{cases} \tag{8}$$

$$W = \begin{cases} 1, & \text{WTP} \leqslant A_1 \\ 0, & \text{other} \end{cases} \tag{9}$$

If the hypothetical utility function is linear,[3] then the utility function expression (1) can be rewritten as:

$$V(Y,X,Q) = \alpha_j + \beta A_1, \quad j = 0,1 \tag{10}$$

Thus, when WTP $\geqslant A_1$, the change of the utility function is expressed as:

$$\Delta V(\cdot) = \alpha_1 - \alpha_0 - \beta A_1 = \alpha - \beta A_1 \tag{11}$$

[3] For simplicity, we only include the market price in the utility function. It is straightforward to derive the WTP with other variables included, such as Q and X; however, it is noted that these two kinds of variables shall be specified as alternative specific variables, instead of generic variables for estimation purposes.

When calculating a driver's WTP, suppose that $F_{WTP}(A_1)$ is a logistic probability model, then the function $F_\varepsilon(\Delta V(\cdot))$ can be expressed as:

$$F_\varepsilon(\Delta V(\cdot)) = \frac{1}{1+e^{-(-\alpha+\beta A_1)}} \tag{12}$$

Expression (6) is further transformed into the following:

$$F_{WTP}(A_1) = \begin{cases} \frac{1}{1+e^{(\alpha-\beta A_1)}}, & \text{if } A_1 > 0 \\ \frac{1}{1+e^{\alpha}}, & \text{if } A_1 = 0 \\ 0, & \text{if } A_1 < 0 \end{cases} \tag{13}$$

α is constant, and β is the marginal utility of the acceptance price. When the driver's WTP is greater than the hypothetical market price (WTP $\geqslant A_1$), the expected driver's WTP is estimated as follows:

$$E(\text{WTP}) = \int_0^\infty (1 - F_{WTP}(A_1))dA_1 - \int_{-\infty}^0 (F_{WTP}(A_1))dA_1 = \frac{1}{\beta}\left\{\lim_{A_1\to\infty}(-\ln(1+e^{(\alpha-\beta A_1)})) + \ln(1+e^{\alpha})\right\} \tag{14}$$

If $A_1 \to \infty$, then the expected WTP can be expressed as follows:

$$E(\text{WTP}) = \frac{1}{\beta}\ln(1+e^{\alpha}) \tag{15}$$

When $F_{WTP}(A_1) = 0$, it defines the spike value. Calculating $A_1 = 0$ creates expression (16):

$$\text{Spike} = \frac{1}{1+e^{\alpha}} \tag{16}$$

4. Questionnaire design and survey analysis

4.1. Questionnaire design

The questionnaire developed in this research is divided into four sections: the first section is primarily the driver's background information; the second section is the driver's travel characteristics; the third section explores the driver's actions and willingness to install an OBU; and the last section includes the scenarios concerning the assumptions of the OBU price and discount. Each section is described as follows.

1. *Driver's background information*. This section asks for the driver's socio-economic background, including age, gender, marital status, occupation and working hours, educational level, personal monthly income, the number of household vehicles, and the number of household OBU-installed vehicles.
2. *Travel characteristics*. This section asks the drivers for their most common travel purposes, e.g., most frequent week of travel, most common time of travel, whether the trip took place at rush hour, the number of freeway usages per month, and whether toll roads are avoided during rush hour.
3. *Actions and willingness to install an OBU*. This section asks correspondents whether they have installed an OBU. For those who have installed an OBU, it inquires about the time of installation, the place of purchase, the time of use since installation, the average amount of value when adding funds, and the average ETC toll per month. In addition to these questions, this section also asks drivers without OBUs installed the reasons for not installing an OBU, their willingness to install an OBU if additional functions are available or if the OBU allows multi-vehicle usage.
4. *Scenario concerning assumptions regarding the OBU price and discount*. The scenario designed in this research follows a dichotomous choice method. First, a starting price point is set, and drivers are asked whether they are willing to pay for an OBU at this price. Then, the first level WTP is used to determine the second level scenario price and continues gauging the respondent's WTP. Three scenario prices are inquired about in this way. The concept is shown in Fig. 1. The past and current OBU prices are used as a reference to determine the scenario prices and the relationship of the price changes. In the first level OBU price range, NT$700 is used as the starting price point. If the driver is willing to accept this price, the next price point is set at NT$1000 and is otherwise set at NT$400. In the second level price range, the price decrease and increase interval is determined by the NT$200 difference between the OBU prices of NT$1000 and NT$1199. The subsequent price setting is performed the same way.

4.2. Data survey

This research uses the National Motor Vehicle Database maintained by the Data Communication Branch of Chunghwa Telecom under the commission of the Ministry of Transportation and Communication. The total number of registered small passenger vehicles in Taiwan is considered to be the population and the total number of registered small passenger vehicles in each county or city to be the subpopulation. After grouping by vehicle types, the data are sampled using systematic sam-

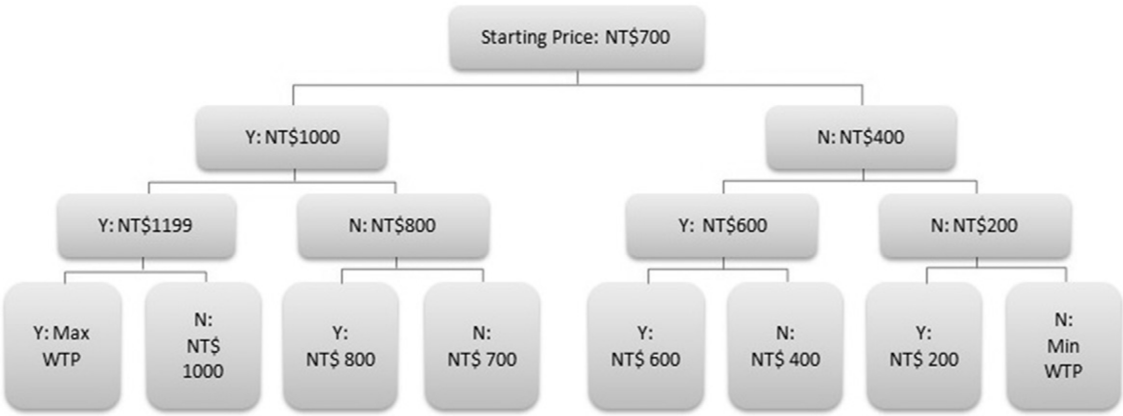

Fig. 1. OBU WTP scenario diagram (*Y* means willing to pay; *N* means not willing to pay).

pling. Prizes were provided to respondents to increase the recovery rate of valid questionnaire responses. In addition, three reminders were sent to those who had not responded to the questionnaire during the survey period to remind them to reply before the deadline. Within the response collection period between November 2010 and December 2010, 1077 valid responses were collected.

The willingness to pay for an OBU varies among the drivers of different travel distances. Therefore, in this study, the travel distances are categorised into three segments: short distance, medium distance, and long distance. Travel distances of 50 km or less are categorised under the short distance segment. Travel distances between 51 km and 150 km are considered medium distances. Travel distances over 151 km are considered long distances. Within all three segments, over 80% of the drivers are male, specifically 85% for short distances, 88% for medium distances, and 84% for long distances. In terms of age, the 50–59 age group has the largest percentages in all segments, 31%, 35%, and 32%, respectively. The primary occupations in all three categories are commercial and services, at 48%, 47%, and 45%, respectively, of which fixed working hours compose the majority at 72%, 71%, and 68%, respectively. The average monthly income is NT$50,000 across all segments. We also find that most households own one to two vehicles, in 82% of the sample, and that over 70% of the respondents do not have an OBU installed.

The primary purpose of travel is visiting friends and relatives (36%, 45%, and 55%, respectively), followed by leisure and tourism (28%, 32%, and 30%); notably, the work or school commute represents 21% in the short distance segment, which is significantly higher than in the other two segments, suggesting that there are varied travel purposes in the short distance segment. Therefore, the drivers' decision-making and their WTP requires further analysis and exploration by segment. Weekends are the most common days of travel in all segments, at 46%, 55%, and 60%, respectively, followed by weekdays, at 27%, 20%, and 17%, respectively. In addition, 20% of the drivers travel daily on the freeway in the short distance segment, which is much higher than in the other two segments. Most travel occurs during non-rush hour in all segments, at 44%, 44%, and 55%, respectively. As the travel distance increases, more drivers tend to travel on freeways during non-rush hour. This tendency is especially obvious in the long distance segment. Nearly 60% of the drivers travel during non-rush hour, possibly because long distance travel requires a longer time; therefore, the drivers tend to travel when the traffic is not congested to reduce the burden of driving. For the frequency of monthly freeway usage, the short distance segment has the highest average (10 times), followed by the medium distance segment (7 times), and, finally, the long distance segment (6 times).

Analysis regarding the OBU installation under each travel distance segment is shown in Table 2. Most drivers do not have an OBU installed. The OBU installation percentages in each segment are 13%, 20%, and 18%, respectively. Among the drivers with an OBU installed, most drivers had the OBU installed three years ago, with percentages of 38%, 52%, and 60%, respectively. In terms of the frequency of OBU usage, the group using the OBU more than 300 times has the highest percentages, at 25%, 35%, and 28%, respectively; most drivers with less than 50 uses are short distance drivers, presumably because these drivers do not pass toll stations during their freeway travels. The major reason for not installing an OBU, according to the statistics, is that these drivers do not travel on the freeway frequently. These less-frequent freeway drivers represent 41%, 45%, and 43% in each segment. Another reason for not installing an OBU is that many drivers think that an OBU is too expensive. Therefore, understanding the driver's WTP and shortening the price-WTP gap by reducing the market price would help improve the OBU installation ratio.

The WTP of drivers in different travel distance segments is shown in Table 3. As shown in Table 3, most drivers are willing to pay NT$200 for an OBU unit, with percentages of 41%, 39%, and 43%, respectively. The average willingness to pay for an OBU unit shows that a driver's average WTP for all segments is lower than NT$350/unit. The short distance segment has the lowest WTP. All of these price points are much lower than the actual sales price. Therefore, the involved government departments should reconsider the OBU sales price to facilitate the policy execution. It shall also be noted that the average WTP

Table 2
OBU installation characteristics.

Item		Short distance	Medium distance	Long distance
OBU installation	Installed	89(13.44)	54(19.78)	25(17.61)
	Not installed	573(86.56)	219(80.22)	117(82.39)
Total samples		662	273	142
OBU installation time	Less than a year	15(16.85)	7(12.96)	2(8)
	1 year ago	11(12.36)	3(5.56)	1(4)
	2 years ago	29(32.58)	16(29.63)	7(28)
	3 years ago	34(38.2)	28(51.85)	15(60)
Frequency of OBU usage after installation	Less than 50	22(24.72)	9(16.67)	2(8)
	50–100	14(15.73)	8(14.81)	6(24)
	101–200	22(24.72)	10(18.52)	6(24)
	200–300	9(10.11)	8(14.81)	4(16)
	More than 300	22(24.72)	19(35.19)	7(28)
Total samples		89	54	25
Reasons for not installing an OBU (multiple answers)	Too expensive	270(37.09)	89(32.25)	56(35.44)
	Installation is not convenient	66(9.07)	28(10.14)	14(8.86)
	Not convenient to add funds	52(7.14)	21(7.61)	14(8.86)
	Do not often travel on the freeway	296(40.66)	123(44.57)	68(43.04)
	Other	44(6.04)	15(5.43)	6(3.8)
Total sample		728	276	158

Note: numbers in parentheses are percentages.

Table 3
OBU Willingness-to-Pay (WTP).

WTP(TWD)	Short distance	Medium distance	Long distance
0	190(28.7)	66(24.18)	40(28.17)
1–199	30(4.53)	10(3.66)	1(0.7)
200	270(40.79)	107(39.19)	61(42.96)
400	30(4.53)	11(4.03)	6(4.23)
600	52(7.85)	25(9.16)	9(6.34)
700	29(4.38)	15(5.49)	3(2.11)
800	42(6.34)	30(10.99)	16(11.27)
1000	13(1.96)	8(2.93)	3(2.11)
1199	2(0.3)	0(0)	1(0.7)
Above 1200	4(0.6)	1(0.37)	2(1.41)
Average	264	314	295
Total	662	273	142

Note: numbers in parentheses are percentages.

values in Table 3 calculated from samples are overweighed by the zero WTP samples which could cause the inconsistent patterns with the expected WTP values estimated from Spike models.

5. Model estimation

This section builds spike models according to travel distance segments to capture the driver's WTP and discusses its influential variables.

5.1. Single variable estimation

This section discusses the driver's WTP with a single variable and estimates the WTP values for short, medium, and long distance segments. The estimated result for the driver's WTP for an OBU is shown in Table 4. The model results show that the scenario price variable is significant and that its negative notation is consistent with expectations. A higher scenario price lowers the driver's tendency to pay for an OBU. The model-estimated driver's WTP for each segment is NT$727/unit, NT$830/unit, and NT$1308/unit, respectively. The table suggests that in each segment, WTP increases as the travel distance increases. The result shows that compared to long distance drivers, medium and short distance drivers are less likely to pay for the OBUs that are sold at current prices, presumably because the time saved from the use of the ETC system is less noticeable and because the current price for an OBU is too high with little leeway.

Table 4
Single variable model estimated result of WTP for an OBU.

Variable	Short distance	Medium distance	Long distance
Constant	0.884(10.23**)	1.123(7.91**)	0.927(4.96**)
Scenario price bid	−0.169(−11.67**)	−0.169(−7.61**)	−.096(−4.01**)
Total sample	662	273	142
Spike value (*t* value)	0.292(16.35)	0.245(9.34**)	0.284(7.48**)
OBU WTP (*t* value)	727(13.12**)	830(8.89**)	1308(4.38**)
SD	55.41	93.36	298.63
Wald statistic (*p* value)	172.250(<0.00)	79.102(<0.00)	19.147(<0.00)

Note: *t*-values are given in parentheses.
** 5% Significance level.

Table 5
Multi-variable estimated result of WTP for an OBU.

Variable	Short distance	Medium distance	Long distance
Constant	1.363(5.28**)	0.812(4.65**)	0.370(1.23)
Scenario price bid	−0.180(−11.70**)	−0.182(−7.58**)	−0.099(−3.98**)
Travel on weekends	0.346(2.16**)	–	–
Less than 3 times per month of freeway travel	−0.306(−1.78*)	–	–
Less than 30 min freeway drive	−0.341(−1.68*)	–	–
Number of household vehicles	−0.188(−2.38**)	–	–
Number of drivers with an OBU	0.764(3.20**)	0.636(2.01**)	–
Travel during morning rush hour	–	0.595(2.31**)	–
Travel on weekends	–	–	0.715(1.94*)
Travel on weekdays	–	–	1.382(1.72*)
Total sample	662	273	142
Spike value (*t* value)	0.294(8.70**)	0.197(5.50**)	0.25(5.62**)
OBU WTP (*t* value)	679(8.98**)	895(7.26**)	1383(4.11**)
SD	75.61	123.28	336.50
Wald Statistic (*p* value)	80.620(<0.00)	52.693(<0.00)	16.925(<0.00)

Note: *t*-values are given in parentheses.
* 10% Significance level.
** 5% Significance level.

5.2. Multi-variable estimation

As described in the introduction, in addition to modelling WTP with a single variable model, the study also uses the spike multi-variable model to estimate the influences and relationships between the drivers' WTP. The spike model's influential variables for each segment are shown in Table 5[4]. The result shows that the negative notation for each model estimation variable is consistent with expectations. Higher scenario prices result in a lower tendency of the driver to pay for an OBU at the scenario price.

We discovered that in the short distance segment, weekend travellers and households which have more drivers with an OBU installed tend to be willing to pay more for OBU's price, possibly because weekend traffic is busier than weekdays, making it is easier to experience congestion, and the OBU installation allows drivers to use the ETC lanes to avoid traffic congestion and save time. For those households which have more drivers with an OBU installed, we speculate that these households are supportive of the ETC system and are therefore the respondent is willing to pay a higher price for the OBU. The drivers with less than three occasions of freeway travel per month or with less than 30 min of freeway travel per trip tend to refuse to purchase an OBU, mainly because they have fewer needs for freeway travel or because their travel distance is short and can be substituted by travelling on regular roads. An OBU provides little benefit to them, and therefore, these drivers are not willing to purchase an OBU. Under the current policy, each OBU can only work with one vehicle, and therefore, the WTP for an OBU decreases as the number of household vehicles increases. In the medium travel distance segment, morning rush hour drivers and the OBU installed drivers are more willing to pay for the OBU, presumably because morning rush hour drivers tend to use the OBU to access the ETC lanes to reduce delays. The reasons that drivers have installed the OBU are the same for those in the short distance segment. In the long distance segment, weekend drivers are more willing to pay for an OBU for the same reason as the short distance segment. Those drivers who commute long distances on weekdays for work are presumably more willing to purchase an OBU to save travel time.

[4] Variables to be included in the model were based on the prior knowledge gained from the previous studies. Most studies in travel behavioral research included socioeconomics and travel characteristics (in addition to, in our study, price bid). Utility functions can be linear and non-linear, we used the concept of stepwise regression, variables in linear form were included in the model first, and then variables in non-linear from. The variables with significant t values were kept in the model.

The comparison of Tables 4 and 5 show that the standard deviation of the coefficient of WTP is smaller for the single variable model (only considering the constant and price), suggesting that the estimation of the single variable model is more accurate than that of the multi-variable model. Therefore, this research uses the WTP estimation from the single variable model as the reference for the pricing recommendation.

6. Results and recommendations

Currently, the major problem with OBUs is the lack of utilisation and the slow utilisation progress. From the price perspective, the willingness to pay for an OBU for short and medium distance drivers are NT$727/unit and NT$830/unit, respectively, lower than the current sales price of NT$1199/unit. The statistics in this study show that most freeway drivers are short or medium distance travellers. Therefore, the government and the operating department should consider adjusting the OBU price, or they could plan to cooperate with other enterprises (e.g., consumers could receive product discounts, exchange for complimentary gifts, and accumulate bonus points, by showing their e-pass cards) to reduce the gap between the WTP of the public and the actual sales price; eventually, they could increase the OBU installation rate.

From the perspectives other than price, the willingness to pay for an OBU for short and medium distance drivers are NT$679/unit and NT$895/unit, respectively, still lower than the current sales price of NT$1199/unit. The results also indicated that the current system is not convenient for travellers in that each OBU only works with one vehicle and cannot be shared with other vehicles. Removing the one vehicle restriction would encourage the use of OBUs.

In addition, feature expansion and integration is recommended (e.g., reducing body size, improving aesthetic design, and adding GPS, driving activity recorder, or real-time traffic information). In addition, adding funds is currently the only feature available on e-pass cards. Thus, feature expansion and integration could also apply to the e-pass cards (e.g., small amount purchasing feature, vehicle payments, and purchase discounts) to attract more users.

Furthermore, to attract drivers without an OBU installed yet or those unfamiliar with the ETC system, we recommend implementing an ETC lane experience program that allows them to drive on ETC lanes and experience the convenience of the non-stop, receipt-free toll collection system. Program details need to be planned by the departments involved.

Some limitations which can be considered as future research are listed as follows. Firstly, the assumed linear form of the utility function in the study may be considered as an approximation from a user behavioural point of view. Secondly, it is true that are several variables, other than price, that affect the adoption of ETC systems. Some of them are discussed in the text (e.g. distance), but others are not justified by the presented results (e.g. aesthetic design, GPS) and can be a research direction in the future.

Finally, the stated preference approach could cause bias. Nevertheless, just like Vehkatachalam (2004) concluded "Even though CV had certain limitations, this method is a promising method and it could be used to derive useful information". Together with the application of Spike model, CV method can obtain much information regarding WTP (especially when the samples contain a high portion of zero WTP).

References

Barreiro, J., Sanchez, M., Viladrich-Grau, M., 2005. How much are people willing to pay for silence? A contingent valuation study. Applied Economics 37, 1233–1246.

Hanley, N., Colombo, S., Kriström, B., Watson, F., 2009. Accounting for negative, zero and positive willingness to pay for landscape change in a national park. Journal of Agricultural Economics 60 (1), 1–16.

Holguín-Veras, J., Preziosi, M., 2011. Behavioral investigation on the factors that determine adoption of an electronic toll collection system: passenger car users. Transportation Research Part C 19, 498–509.

Hu, W., 2006. Use of spike models in measuring consumers' willingness to pay for Non-GM oil. Journal of Agricultural and Applied Economics 38 (3), 525–538.

Jou, R.C., Chen, K.H., 2012. Highway drivers' willingness-to-pay for speeding behavior in Taiwan. Journal of Advanced Transportation, forthcoming.

Jou, R.C., Wang, P.L., 2012. The intention and willingness to pay moving violation citations among Taiwan motorcyclists. Accident Analysis & Prevention 49, 177–185.

Jou, R.C., Wu, Y.C., Chen, K.H., 2011b. Analysis of the environmental benefits of a motorcycle idling stop policy at urban intersections. Transportation 38 (6), 1017–1033.

Jou, R.-C., Chiou, Y.C., Chen, K.H., Tan, H.I., 2012b. Freeway drivers' willingness-to-pay for a distance-based toll rate. Transportation Research Part A 46 (3), 549–559.

Kriström, B., 1997. Spike models in contingent valuation. American Journal of Agricultural Economics 79 (3), 1013–1023.

Lee, W.H., Tseng, S.S., Wang, C.H., 2008. Design and implementation of electronic toll collection system based on vehicle positioning system techniques. Computer Communications 31 (12), 2925–2933.

Levinson, D., Chang, E., 2003. A model for optimizing electronic toll collection systems. Transportation Research Part A 37, 293–314.

McCartney, A., 2006. The social value of seascapes in the Jurien Bay Marine Park: an assessment of positive and negative preferences for change. Journal of Agricultural Economics 57 (3), 577–594.

Ogden, K.W., 2001. Privacy issue in electronic toll collection. Transportation Research Part C 9, 123–134.

Riley, P.F., 2008. The tolls of privacy: an underestimated roadblock for electronic toll collection usage. Computer Law & Security Report 24, 521–528.

Saz-Salazar, S.D., Garcia-Menendez, L., 2001. Willingness to pay for environmental improvements in a large city. Environmental and Resource Economics 20, 103–112.

Taiwan Area National Freeway Bureau, 2010. A Study on the Distance-based Electronic Toll Rate. Research Report, Taiwan Area National Freeway Bureau, Ministry of Transportation and Communications, Taiwan.

Taiwan Area National Freeway Bureau, 2011. Capture date January 11, 2012 <http://www.freeway.gov.tw/Publish.aspx?cnid=1472&p=488>.

Vehkatachalam, L., 2004. The contingent valuation method: a review. Environmental Impact Assessment Review 24, 89–124.

Yoo, S.H., Shin, C.O., Kwak, S.J., 2006. Inconvenience cost of spam mail: a contingent valuation study. Applied Economics Letters 13, 933–936.