Transportation Research Part E 49 (2013) 266–280

Contents lists available at SciVerse ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

The adoption behaviours of freeway electronic toll collection: A latent class modelling approach

Yu-Chiun Chiou [a,*], Rong-Chang Jou [b], Chu-Yun Kao [a], Chiang Fu [a]

[a] Institute of Traffic and Transportation, National Chiao Tung University, 4F, 118, Sec. 1, Chung-Hsiao W. Rd., Taipei 10012, Taiwan, ROC
[b] Department of Civil Engineering, National Chi Nan University, No. 1, University Rd., Puli, Nantou County 54561, Taiwan, ROC

ARTICLE INFO

Article history:
Received 12 March 2012
Received in revised form 11 July 2012
Accepted 18 September 2012

Keywords:
Electronic toll collection
Discrete choice model
Latent class model

ABSTRACT

This study develops an electronic toll collection (ETC) disaggregate choice model based on a large-scale questionnaire survey of car drivers in Taiwan. To acknowledge the difference in preferences among car drivers, the latent class logit model is used to classify respondents into different groups without subjective segmentation. The estimation results show that six groups of car drivers are optimally distinguished. The price of an e-pass and the discount for ETC tolls are identified as the two most important factors affecting ETC adoption. The study also finds that significant differences in adoption behaviours exist among groups. Effective marketing strategies for different groups are then proposed accordingly.

1. Introduction

The adoption of congestion pricing for toll collection can recover road construction and operation costs, reducing the fiscal burden of the government. More importantly, it can be used to effectively manage the traffic demand and improve the efficiency of road usage. Therefore, congestion pricing has not only attracted considerable attention among academic researchers but has also been widely adopted and put into practice by various countries. This practice is especially common for freeways, which have high investment costs and a high level of service requirements. Initial freeway toll collection systems were often manual; however, the development of electronic technology and the ever-increasing requirements for transport efficiency have led to the gradual replacement of many manual toll collection systems with electronic toll collection systems.

In Taiwan, for example, freeways fees are collected by manual mainline-barrier toll collection system and the toll rate cannot be automatically adjusted according to the traffic flow to achieve congestion pricing. Moreover, the locations of toll stations are subject to land use restrictions, and thus, toll stations cannot be installed universally and evenly, resulting in approximately 60% of freeway travellers do not pay a toll leading to serious congestion of urban segments and an impact on the overall service level of freeway.

To enhance the efficiency of freeway usage and implement the principle of user fees, the Taiwanese government decided to promote an electronic toll collection policy in phases starting in 2004. During the first phase, some manual toll lanes that charge fees based on usage frequency were converted to electronic toll lanes and were formally put into operation on February 9th, 2005. Once the ETC usage rate reaches a certain level, the distance-based ETC system will be put into practice on all freeways during the second phase (2013). However, poor usage rates, less than 50% (Fig. 1) have lead to considerable challenges in the implementation of the distance-based toll policy. One of the most important factors impeding ETC usage is the fact that the user is required to pay for the installation of the on-board unit (i.e., the e-pass). It should be noted that the usage

* Corresponding author. Tel.: +886 2 23494940.
E-mail address: ycchiou@mail.nctu.edu.tw (Y.-C. Chiou).

1366-5545/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tre.2012.09.003

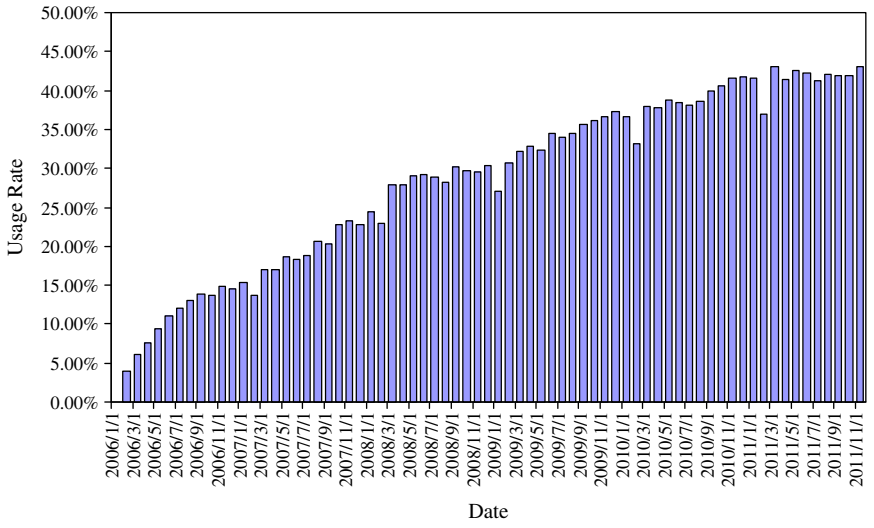

Fig. 1. ETC usage rate in Taiwan.

rate (defined as the number of vehicles with e-pass passing toll stations/the number of total vehicles passing toll stations) was much higher than the adoption rate (=the number of vehicles with e-pass/the number of total registered vehicles) especially at the early stage of ETC system installation, because frequent users are more likely to adopt an e-pass and contribute more toll transactions.

Because the distance-based freeway ETC system is new, it is particularly important to understand the ETC adoption and usage behaviour of future freeway users. ETC has been studied extensively, with most studies using the multinomial logit model (Holguín-Veras and Preziosi, 2010) or structural equation modelling (Chen et al., 2007; Jou et al., 2011) to explore the preference and behaviour of freeway users under the ETC system. For instance, some studies have used structural equations to modify new models (e.g., the theory of planned behaviour, the technology acceptance model) to investigate the low ratio of drivers installing ETC equipment and using the ETC service (Chen et al., 2007). Other studies have discussed the impact of the media and point to anecdotal evidence of the effectiveness of ETC equipment (Jou et al., 2011) and the willing-to-pay toll rate for distance-based ETC system (Jou et al., 2012). Holguín-Veras and Preziosi (2010) investigated and analysed the determinants of motorist use in the ETC system. They used the data from the ETC system in the New York area, such as individual socio-economic background and travel characteristics, and analysed the data using a discrete choice model. They also surveyed ETC users on their preferences, on the advantages and disadvantages of ETC, and on reasons for not using the system.

As shown in the above discussion, only a few studies aimed to explore how to increase the ETC usage rate. In general, there are many approaches to increasing market share, especially if complemented by good marketing strategies. However, an effective marketing strategy must be able to effectively segment the market and also specifically target different market segments. Market segmentation classifies consumers with similar market demands into groups and thus forms many different sub-markets. There are some significantly different preferences between sub-markets that enable the marketing staff to develop strategies targeting different consumer needs more effectively (Smith, 1956). The majority of studies segment the market according to characteristics such as gender and income to explore the users' preferences. In fact, many individual socio-economic and travel characteristics could be used as market segmentation factors, but segmentation should not be limited to a single variable (or segment characteristics). Instead, multi-dimensional segmentation characteristics should be considered to reflect various characteristics of the sample market.

With all these factors in mind, this study performed market segmentation using the latent class model (LCM) for estimation and prediction, with the hope of more accurately capturing information on the preferences of freeway users in each group for the distance-based ETC system. This study provided four alternatives to freeway users: a traditional e-pass, a GPS navigation service plus e-pass, an experiential marketing plan, and a plan that involved mailing a bill at the end of each month. The four alternatives are further explained in Table 1. The results of this study will contribute to the development of an appropriate combination of marketing strategies to enhance the ETC usage rate.

LCM was originally introduced by Lazarsfeld and Henry (1968) as a way of formulating latent attitudinal variables from dichotomous survey items. LCM is a semi-parametric model (Greene and Hensher, 2003) and is similar to the mixed logit model. Although the LCM is less flexible than the mixed logit model, LCM does not require the assumption that the parameters obey a specific distribution. Therefore, the LCM is increasingly common in the field of transportation research (Bhat, 1997; Greene and Hensher, 2003; Wen and Lai, 2010).

Table 1
Experimental design to study stated preferences for the distance-based ETC system.

Alternatives	A Traditional e-pass	B GPS e-pass	C Experiential marketing plan	D End-of-month billing plan
Purchase price (NT$)	850 1050 1200	6000 8500 10,000	–	–
Miles refund/redeem	No refund Refund after 6500 km	–	Miles redeemed for a free e-pass: 8500 km Miles redeemed for a free e-pass: 10,000 km	–
Billing cost (NT$)	–	–	–	33 88
Toll discount	5% 10% 28%	7% 15% 25%	No toll discount	No toll discount

Based on the above-mentioned information, this study investigated motorists' socio-economic and travel characteristics as well as their ETC adoption behaviour and preferences. The stated preference (SP) approach was used to design the questionnaire, and the LCM was used for calibration. Significant variables affecting freeway users' preferences for the distance-based ETC system were investigated. This study surveyed drivers of private passenger vehicles in Taiwan and identified respondents through systematic sampling. In this study, the LCM was combined with the ETC choice model and market segmentation. The model assumed that a heterogeneity of preference existed among market segments and that the segmentation variables could be obtained from the estimation results. In addition to investigating the heterogeneity of freeway users among market segments, an ETC system preference was also identified in each market segment. Finally, according to the estimation results of the model, marketing strategies were developed for various market segments to simulate the demand and response under the ETC system and serve as a reference for ETC system managers.

The rest of this paper is organised as follows. First, a brief introduction to the LCM model is provided in Section 2. Section 3 presents the questionnaire design and survey along with some descriptive statistics. Model estimation results along with some policy implications are provided in Section 4. Finally, concluding remarks and suggestions for future studies are presented.

2. Latent class model

The LCM used in this study was derived from the traditional discrete choice model. The basic framework of the discrete choice model is based on the economic utility function as a starting point, assuming that decision-makers make rational choices in pursuit of utility maximisation by considering all alternatives and selecting the alternative that provides the greatest utility. This study adopted the discrete choice model, assuming that when facing many ETC alternatives (A_n), a freeway user would select the ETC alternative that provides the maximum utility. The utility function between freeway user n and ETC alternative i is expressed in the following equation:

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

where V_{in} is the measurable utility that alternative i brings to freeway user n and ε_{in} is the random error that alternative i brings to freeway user n.

Assuming that the error term obeys the Gumbel distribution, then the formula for the probability of the multinomial logit model can be derived under the assumption of the utility maximisation principle, as shown in the following equation:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in A_n} e^{V_{in}}}, \quad \forall i, j \in A_n \tag{2}$$

Here, P_{in} is the probability that freeway user n chooses alternative i, and V_{in} is the systematic utility that alternative i brings to freeway user n.

The LCM was established based on the discrete choice model (Bhat, 1997; Bijmolt et al., 2004; Bhatnagar and Ghose, 2004), assuming that the preference of decision-makers could be divided into a finite number of segments with homogeneity among freeway users' preferences in each segment. The probability that various alternatives are chosen by a freeway user can be broken down into two parts. The first part expresses the probability of alternatives chosen in a given segment, and the second part is the probability that a freeway user belongs to a given segment. Both are expressed by the formula for probability obtained using the logit model. The probability function of a freeway user belonging to a given segment was assumed to be related to the characteristics of the freeway user.

Suppose that there are s segments but that it is unknown which segment each freeway user belongs to. In this case, there are j alternatives in A_n. The probability that ETC alternative i is chosen by freeway user n in segment s is expressed in the following equation:

$$P_n(i|s) = \frac{\exp(\beta_s X_{in})}{\sum_{j \in A_n} \exp(\beta_s X_{jn})} \tag{3}$$

where β_s is the parameter to be estimated in segment s and X_{in} is the attribute of freeway user n towards alternative i.

The probability that freeway user n belongs to segment s can also be expressed by the multinomial logit model as follows:

$$Q_n(s) = \frac{\exp(z_n \theta_s)}{\sum_{s=1}^{S} \exp(z_n \theta_s)}, \quad s = 1, 2, \ldots S \tag{4}$$

where β_s is the estimation parameter of the segmentation function and z_n is the observed characteristic of the motorist.

The probability mentioned above and the probability of ETC alternative i chosen by freeway user n in a finite number of market segmentations s could be expressed in the following equation:

$$P_n(i) = \sum_{s=1}^{S} P_n(i|s) \cdot Q_n(s) \tag{5}$$

The likelihood function value is expressed as follows:

$$\ln L = \sum_{n=1}^{N} \ln P_n = \sum_{n=1}^{N} \ln \left[\sum_{s=1}^{S} P_n(i|s) \cdot Q_n(s) \right] \tag{6}$$

Because the number of segments could not be determined in advance in the LCM, it was determined through commonly used performance indicators such as the Bayesian Information Criterion (BIC) and the Constrained Akaike Information Criterion (CAIC). The number of segments was determined by starting with two segments and adding one segment at a time until the additional segment no longer significantly improved the goodness-of-fit level of the model, with the optimal number of market segments taken as the number beyond which no improvement was obtained. The larger the number of segments, the less the goodness-of-fit level could be improved (Kemperman and Timmermans, 2009). Therefore, the number of segments that led to the greatest improvement in the goodness-of-fit level was taken as the optimal segment number. The calculation methods used here are shown in the following equations:

$$AIC = -2LL(\beta) + 2K \tag{7}$$

$$BIC = -2LL(\beta) + K \ln(N) \tag{8}$$

Here, $LL(\beta)$ is the logarithmic likelihood function value, K is the number of parameters, and N is the total number of samples.

3. Questionnaire design and survey

To understand the adoption behaviour of the ETC system by drivers of private passenger vehicles, this study conducted a questionnaire survey to obtain the data required to build the LCM. This section will focus on the questionnaire design and content, the questionnaire survey method, and the results of the descriptive analysis.

3.1. Questionnaire design

The questionnaire used in this study can be broadly divided into two major parts. The first part was related to revealed preference and was aimed at understanding the motorist's adoption and usage of the ETC system, which were also used as the variables of segment characteristics that included socio-economic data, freeway usage patterns, and ETC adoption behaviour and preferences. Variables suitable for the LCM were obtained through item design. The second part was related to the stated preference. The scenario questions were designed with a stated preference method that set the standard value of different attributes such that respondents could choose from different alternatives.

3.1.1. Revealed preference items

The adoption behaviour of the freeway ETC system was mainly influenced by socio-economic background and freeway usage patterns. Motorists with different socio-economic and travel characteristics also chose different alternatives. Items were also designed to understand the drivers' adoption behaviour and preferences for the ETC system. The following is an explanation of the item design of the questionnaire survey for drivers of private passenger vehicles in Taiwan.

Part I: Freeway usage pattern: This part was aimed at understanding the respondent's freeway usage behaviour. The items included the freeway on and off ramps used, travel frequency (monthly), travel purpose, and travel time.

Part II: ETC adoption behaviour and preferences: The current situation of the respondents was surveyed, including whether the ETC system was adopted, the time and frequency of usage, and the place of purchase. In addition, items about

the recently introduced experiential marketing plan were added. The questionnaire included items such as whether respondents participated in the experiential marketing plan, their level of satisfaction with the plan, and their source of information regarding the ETC.

Part III: Relevant data on the primary driver: This section examined the primary driver's socio-economic data, including gender, age, occupation, job, education level, average monthly income, and the number of cars in the driver's household.

3.1.2. Stated preference items

The stated preference method was used to resolve situations where future patterns could not be shown or were not yet mature enough to enable prediction. Freeway fees are currently charged based on usage frequency and will be charged based on travel distance in 2013. Therefore, this study used a stated preference design to understand motorists' preferences on the future distance-based ETC system.

This study designed four distance-based ETC alternatives for respondents to choose from: (1) traditional e-pass; (2) GPS navigation service plus e-pass plan (GPS e-pass); (3) experiential marketing plan; and (4) end-of-month billing plan. Both experiential marketing plan and end-of-month billing plan are designed for those vehicles without equipped ETC on-board unit (i.e. e-pass) and use of license plate recognition technology to identify the vehicles passing ETC toll gates. The former requires drivers to enrol their license plate and to pre-store money to a designated account in advance. The ETC system automatically deducts the toll fee from the account per transaction. After a certain number of successful transactions (8500 or 10,000 km), drivers can get an e-pass for free. The latter is to send users a bill of total toll fees for all transactions within the month at the end of month.

To understand the respondents' preferences for the ETC system, the four alternatives were designed experimentally and their attribute variables and standard values were set as shown in Table 1.

Based on the experimental design, under the distance-based ETC system, there were 18 scenarios for the traditional e-pass, nine combinations of purchase price and toll discount for the GPS e-pass, two scenarios for the experimental marketing plan with different accumulated miles redeemed for a free e-pass, and two scenarios for the end-of-the-month billing plan with different billing costs.

To avoid requiring respondents to consider too many scenarios at the same time, the orthogonal design method based on experimental design theory was used to reduce the number of combinations. In this study, the statistical software SPSS 17.0 was used for the orthogonal design and produced a total of 16 scenarios. Due to the restrictions of the questionnaire, the number of scenarios after reduction was still too large. We then removed the clearly superior scenarios where all attribute standard values were superior. Finally, nine scenarios remained and were randomly allocated to three types of questionnaires (Table 2).

The nine scenarios mentioned above were allocated to questionnaires A, B, and C which contained three scenarios each. One type of questionnaire was randomly chosen for each respondent.

3.2. Questionnaire survey

The purpose of this study was to understand the ETC adoption behaviour of motorists. Drivers of private passenger cars were surveyed. The survey covered Taiwan, and the required samples were obtained through systematic sampling. Since the survey was large-scale and the questionnaire was rather lengthy, the questionnaires were distributed by post-mail, instead of face-to-face or telephone interviews.

The private passenger car registrations of all of Taiwan constituted the sampling group. The required number of samples was obtained through systematic sampling. A total of 70,000 questionnaires were mailed in December 2010. Three letters were sent successively during the survey period to remind respondents that had yet to return the questionnaire to respond before the deadline. The first batch of questionnaires was mailed on December 1st, 2010, and the response deadline was December 15th, 2010. A total of 70,000 questionnaires were mailed, and on December 17th, 22nd and 27th, 2010, letters

Table 2
Survey scenarios.

Scenarios	Traditional e-pass			GPS e-pass		Experiential marketing plan	End-of-month billing plan
	Purchase price (NT$)	Toll discount (%)	e-pass refund miles (km)	Purchase price (NT$)	Toll discount (%)	e-pass redeem miles (km)	Billing cost (NT$)
1	1200	28	No refund	10,000	25	8500	33
2	850	28	No refund	6000	15	10,000	88
3	850	10	6500	10,000	7	8500	88
4	1050	5	6500	6000	25	8500	88
5	850	5	6500	10,000	15	10,000	33
6	850	5	6500	8500	25	10,000	33
7	1200	5	6500	6000	15	8500	88
8	1200	10	6500	6000	7	10,000	33
9	1050	28	6500	6000	7	10,000	33

Table 3
Adoption of toll collection alternatives.

Required advance deposit	Toll collection alternatives	Samples	Percentage (%)
Yes	Traditional e-pass	7678	37.1
	GPS e-pass	1545	7.5
	Experiential marketing plan	4675	22.6
No	End-of-month billing plan	6802	32.9
Total	20,700	100.0	

were sent to remind respondents that had not yet responded to return the questionnaire. As of January 5th, 2011, a total of 7053 questionnaires were returned. Among the questionnaires returned, a total of 6900 were valid and 153 were invalid. The effective ratio was 97.83%, and the questionnaire response rate was 10.08%.

3.3. Descriptive analysis

As shown in Table 3, the percentages of respondents that chose the traditional e-pass, GPS e-pass, and experiential marketing plans were 37.1%, 7.5% and 22.6%, respectively. These three advance deposit choices together accounted for 67.1% of respondents, with 32.9% of respondents choosing the end-of-month billing plan. The results show that 67.1% of respondents preferred the advance deposit payment method and that the most popular system was the traditional e-pass.

3.4. Analysis of sample characteristics

The sample characteristics, their frequency, and their proportion were analysed. The characteristics analysed mainly included the freeway usage pattern, ETC adoption, adoption of the experiential marketing plan, and socio-economic data on the primary driver. The frequency and proportion of questionnaire data are summarised in Table 4 and described below.

With regard to the freeway usage pattern, 60.9% of trips were shorter than 50 km, followed by 11.9% that were between 51 and 100 km in length. Moreover, 44.4% of respondents used the freeway less than three times each month, followed by 27.2% that used it 4–7 times each month. As for the usage during rush hour, 39.7% of respondents used the freeway for both outbound and return travels, while 26.9% did not use the freeway for either trip.

The majority of respondents, 83.2%, had not yet adopted e-pass. The survey of the usage behaviour of the 16.8% of respondents that were e-pass adopters showed that 35.9% had adopted e-pass 3 years earlier and that another 18% had adopted it 2 years earlier. From the results of analysing e-pass usage frequency, 29.7% had used e-pass more than 300 times, followed by 20.4%, 18.9%, and 19.6% that had used e-pass less than 50 times, 50–100 times, and 100–200 times, respectively. As for the incidence of charge failure due to ETC equipment issues from Far Eastern Electronic Toll Collection Co. (FETC), 67.4% never experienced charge failure. From the results of analysing the purchase location, 53.4% of adopters purchased the e-pass at FETC electronic stores, followed by 19.2% who purchased it at FETC direct or franchise outlets.

More than half of the respondents, 52.4%, had never heard about the experiential marketing plan, and only 47.6% were familiar with the name of the plan. Among people who knew of the plan, 56.2% learned of it from television broadcasting. When asked for their opinion of the experiential marketing plan, 43.5% had no opinion, followed by 17.23% who were partially in favour of the alternative arrangement. Currently, only 5.2% participate in the experiential marketing plan.

The primary drivers were mainly male and accounted for 84.93%, while females accounted for only 15.07%. The age distribution of primary drivers was as follows: 33.80% were between 50 and 59 years of age, followed by 23.1% who were between 40 and 49 years of age. The groups of primary drivers that were younger than 20 years of age or between 20 and 29 years of age accounted for 1.2% and 5.7%, respectively. As for the occupation of the primary drivers, 39.8% engaged in business and services, followed by 21.4% and 19.4% who were workers and military/civil/teaching personnel, respectively. Regarding the drivers' education level, 44.7% had a college education, followed by 29.5% who had a high school education. As for the average individual monthly income of primary drivers, 28.9% had an income of 20,000–40,000 NT$/month and 28.9% had an income of 40,000–60,000 NT$/month, followed by 19.5% who had an income of less than 20,000 NT$/month. In total, approximately 77% of households reported an income of 0–60,000 NT$/month. Only a small number of households had incomes of 100,000–120,000 NT$/month or 120,000 NT$/month or greater, accounting for only 2.7% and 0.6%, respectively. Approximately 43.7% of households owned one car, followed by 37.5% with two cars.

To further ensure the distribution of our sampled drivers was in line with that of population, chi-square tests on some demographic variables were performed, including gender, age, education, and income with chi-square values of 3.57, 10.42, 1.68, and 5.67, respectively which were lower than the critical chi-square values of 3.84, 11.07, 9.49, and 9.49 at the significance level of 0.05, suggesting the representation of our samples although the valid returned ration is only 10.08%.

4. Estimation results

To better show the necessity in developing a latent class model (LCM) for explaining the ETC adoption behaviours, a traditional multinomial logit model (MNL) is first estimated, followed by the estimation of the LCM model based on the esti-

Table 4
Summary of the questionnaire data.

Category	Item		Samples	Percentage (%)
Freeway usage pattern	Travel distance (km)	<50	4203	60.9
		51–100	821	11.9
		101–150	665	9.6
		151–200	607	8.8
		>201	604	8.8
	Freeway usage frequency (Times/month)	>30	384	5.6
		20–29	599	8.7
		8–19	973	14.1
		4–7	1880	27.2
		<3	3064	44.4
	Usage during rush hour	Both outbound and return travels	2739	39.7
		Outbound travel, but not return travel	1212	17.6
		Return travel, but not outbound travel	1094	15.9
		Neither outbound nor return travel	1855	26.9
ETC adoption	e-Pass adoption	Yes	1159	16.8
		No	5741	83.2
	Time of e-pass adoption	1 month ago	60	5.2
		3 months ago	51	4.4
		6 months ago	54	4.7
		1 year ago	135	11.6
		1.5 years ago	121	10.4
		2 years ago	209	18.0
		2.5 years ago	113	9.7
		3 years ago	416	35.9
	Usage frequency	<50 times	237	20.4
		51–100 times	219	18.9
		101–200 times	227	19.6
		201–300 times	132	11.4
		>301 times	344	29.7
	Incidence of debit failure	0 times	781	67.4
		1–5 times	323	27.9
		6–10 times	34	2.9
		11–15 times	13	1.1
		>15 times	8	0.7
	Place of purchase	FETC electronic stores	619	53.4
		FETC direct or franchise outlets	223	19.2
		Arcoa communication Co. outlets	18	1.6
		Car depot	93	8.0
		Automotive department store	24	2.1
		Vehicle maintenance and repair plant	73	6.3
		3C hypermarket	63	5.4
		Gas station	32	2.8
		Other	14	1.2
Adoption of the experiential marketing plan	Heard of	Yes	3284	47.6
		No	3616	52.4
	Information source	FETC stores	295	9.0
		Television broadcasting	1847	56.2
		Internet	271	8.3
		Newspapers and magazines	649	19.8
		Relatives and friends	218	6.6
		Other	4	0.1
	Favour experiential marketing plan?	Completely disapprove	1049	15.2
		Somewhat disapprove	516	7.5
		No opinion	2999	43.5
		Partially in favour of	1189	17.2
		Completely in favour of	1147	16.6
	Adoption?	Yes	359	5.2
		No	6541	94.8
Socio-economic data of primary driver	Gender	Male	5860	84.9
		Female	1040	15.1
	Age (years)	<20	84	1.2
		20–29	390	5.7
		30–39	1222	17.7
		40–49	1592	23.1
		50–59	2332	33.8
		>60	1280	18.6
	Occupation	Military/civil/teaching personnel	1341	19.4

Table 4 (*continued*)

Category	Item		Samples	Percentage (%)
		Workers	1478	21.4
		Business/services	2743	39.8
		Agriculture, forestry, fishing, herding	299	4.3
		Student	2	0
		Unemployed	1028	14.9
		Other	9	0.1
	Education level	Below primary school	456	6.6
		Middle school	574	8.3
		High school	2035	29.5
		College	3085	44.7
		Post-graduate (Master's)	672	9.7
		Post-graduate (Ph.D.)	78	1.1
	Average monthly income (×10,000 NT$)	<2	1344	19.5
		2–4	1998	28.9
		4–6	2000	28.9
		6–8	961	13.9
		8–10	365	5.3
		10–12	188	2.7
		12 or higher	44	0.6
	No. of household cars	0	89	1.3
		1	3017	43.7
		2	2587	37.5
		3	871	12.6
		4	295	4.3
		5 or more	41	0.6

mation results of the MNL model. At last, based on the estimation results of the LCM model, corresponding marketing strategies for different market segmentations are then proposed with potential marketing performances (market shares) predicted.

4.1. Multinomial logit model

Table 5 shows the estimation results of the multinomial logit model for the distance-based ETC system. The explanatory powers at the primary and revised goodness-of-fit levels were only 12% and 4%, respectively, which may have resulted from the sample heterogeneity. When $P < 0.05$ was considered statistically significant, all variables had significant effects, except 'the purchase price refund.' As for the inertia variable analysis of various stated preference scenarios, a positive maintenance

Table 5
Estimation results of the MNL model.

Variable	Coefficient	*t*-value
Traditional e-pass	−0.486	−6.91***
GPS-e-pass	−0.756	−3.59***
Experiential marketing plan	−0.214	−2.37***
End-of-month billing plan	Base value	–
Those who adopted e-pass → traditional e-pass	1.881	33.82***
Those who adopted e-pass → GPS e-pass	0.838	4.73***
Experiential marketing plan → traditional e-pass	0.530	5.41***
Experiential marketing plan → end-of-month billing plan	0.355	3.12***
Those who did not adopt e-pass → GPS e-pass	−0.654	−3.67***
Those who did not adopt e-pass → Experiential marketing plan	−0.435	−6.00***
Purchase price (unit: 10,000 NT$)	−0.884	−6.02***
Toll discount (unit: 10%)	0.011	6.24***
Miles refund/redeem (unit: 10,000 km)	−0.002	−0.43
Billing cost (unit: 10 NT$)	−0.004	−6.99
Convergence likelihood value	−25158.03	
$\rho^2(\rho_c^2)$	0.12(0.04)	
Samples (respondents)	20,700 (6900)	

Note: The inertia variable is expressed as actual behaviour → adoption behaviour.
*P-value < 0.1.
**P-value < 0.05.
***P-value < 0.01.

Table 6
Determination of the number of groups.

No. of groups (parameters)	4(37)	5(45)	6(53)	7(61)
Convergence likelihood value	−15701.93	−15642.62	−15560.48	−15651.8
AIC	31477.86	31375.24	31226.96	31417.34
BIC	31771.56	31732.45	31647.67	31901.55

Table 7
Adoption probability of alternatives in each segment under the distance-based ETC system.

Models	LCM						MNL
Alternatives	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 5 (%)	Group 6 (%)	Overall
Traditional e-pass	93.5	4.1	6.4	15.3	0.0	57.9	37.1
GPS e-pass	1.1	0.6	87.4	3.5	0.0	21.5	7.5
Experiential marketing plan	2.4	1.2	4.2	78.3	99.4	9.6	22.6
End-of-month billing plan	3.0	94.1	2.0	2.9	0.6	11.0	32.9

and transfer of inertia was found for the choices of "traditional e-pass" and "GPS e-pass" from drivers that had adopted e-pass, indicating that those drivers tended to maintain their previous adoption behaviour or preferred to switch to GPS e-pass. Among drivers with the experiential marketing plan, there was a positive transfer of inertia to the choices of "traditional e-pass" and the "end-of-month billing plan", and the shown preference deserves marketing attention. Among those who did not adopt e-pass, a negative transfer of inertia was observed for the choices of "GPS e-pass" and "experiential marketing plan," suggesting that the added features of the e-pass and the continuous promotion of the experiential marketing plan did not attract the attention of those who did not yet adopt e-pass, as expected. All signs of the generic variables of the model were in compliance with the expectations of this study. The lack of significance in the "miles refund/redeem" may be due to the drivers' inability to accurately calculate travel distance as opposed to usage frequency, especially given that the distance was converted into kilometres. Moreover, variables of purchase price and billing operation cost were negatively significant, while toll discount was positively significant. Purchase price had the largest effect on the adoption of the ETC system, followed by toll discount.

4.2. Latent class model

Based on the estimation results of the MNL model, this study further established the LCM model to understand motorists' ETC adoption preferences in different market segments. Table 6 showed the performance indicators in the model calculated for various numbers of groups. These values were relatively smaller as there were six groups. When the number of groups exceeds the optimal number of segments, AIC and BIC deteriorate because of the ever-increasing number of input variables. Therefore, the number of segments was eventually set at six.

Table 7 presents the adoption probability of alternatives in each segment under the distance-based ETC system. As shown in the table. "traditional e-pass" was the most preferred alternative in Group 1. "GPS e-pass" was the most preferred alternative in Group 3. "experiential marketing plan" was the preference of both Groups 4 and 5 under the distance-based ETC system. The end-of-month billing plan was the most favoured alternative in Group 2. As for Group 6, the "traditional e-pass" was favoured, followed by "GPS e-pass" and the "end-of-month billing plan".

Table 8 presents the estimation results of the LCM. The signs of the explanatory variables were correct and significant. After grouping, for the inertial variables for those who did not adopt e-pass, all signs of both "those that did not adopt e-pass → GPS e-pass" and "those that did not adopt e-pass → experiential marketing plan" changed from negative to positive (compared to MNL). On the contrary, the experiential marketing plan transfer characteristics variables, "experiential marketing plan → traditional e-pass" and "experiential marketing plan → the end-of-month billing plan", changed from positive to negative. The analysis results of the LCM model showed that appropriate experimental design and market segmentation improved the heterogeneity of the original MNL model, truthfully reflecting the preferences of respondents and aiding marketing interpretation. Regarding the significance of the coefficients, all marketing strategies were ineffective in Group 5. Furthermore, with regard to the main variables within groups, purchase price and billing operation costs had relatively stronger effects and affected four out of six groups. The effect of "miles refund/redeem" was the weakest and was empirically confirmed to have the desired effect in only two out of six groups. Purchase price was the biggest concern for Group 3, suggesting that an appropriate pricing strategy is the main driver boosting a driver's adoption of the high-priced "GPS e-pass." Groups 2 and 6 also reported a considerable concern regarding the purchase price. Toll discount exerted the strongest effect on Group 6, followed by Group 4. "Miles refund/redeem" exerted the strongest effect on Group 1, followed by Group 6. Billing cost affected Group 1 the most, followed by Groups 2 and 4.

Table 8
Estimation results of the LCM model.

Variable	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Constants												
Traditional e-pass	1.682	3.61***	−4.234	−7.32***	1.106	1.17	−0.909	−1.99***	−4.659	−0.02	−0.820	−1.89**
GPS e-pass	−2.839	−2.61***	−6.083	−4.76***	4.733	4.26	−1.739	−2.02***	−1.134	0.00	−1.009	−1.18
Experiential marketing plan	−4.329	−9.64***	−5.560	−10.47***	0.581	0.59	0.913	2.03***	2.715	0.05	−2.987	−6.58***
End-of-month billing plan	Base value	–	Base value	–	Base value	–	Base value	–	Base value	–	Base value	–
Inertia Variables												
Those who adopted e-pass → pay to adopt e-pass	2.291	12.91***	2.291	12.91***	2.291	12.91***	2.291	12.91***	2.291	12.91***	2.291	12.91***
Those who adopted e-pass → GPS e-pass	2.450	4.60***	2.450	4.60***	2.450	4.60***	2.450	4.60***	2.450	4.60***	2.450	4.60***
Experiential marketing plan → traditional e-pass	−0.435	−1.68	−0.435	−1.68**	−0.435	−1.68**	−0.435	−1.68**	−0.435	−1.68**	−0.435	−1.68**
Experiential marketing plan → End-of-month bill plan	−0.899	−2.53***	−0.899	−2.53***	−0.899	−2.53***	−0.899	−2.53***	−0.899	−2.53***	−0.899	−2.53***
Those who did not adopt e-pass → GPS e-pass	1.074	2.00***	1.074	2.00***	1.074	2.00***	1.074	2.00***	1.074	2.00***	1.074	2.00***
Those who did not adopt e-pass → experiential marketing plan	1.485	6.18***	1.485	6.18***	1.485	6.18***	1.485	6.18***	1.485	6.18***	1.485	6.18***
Generic Variables												
Purchase price (unit: 10,000 NT$)	−0.606	−0.50	−2.732	−1.72**	−4.081	−4.49***	−1.796	−2.18***	−3.186	0.00	−2.246	−3.76***
Toll discount (unit: 10%)	−0.041	−2.74***	0.009	0.49	0.036	1.72**	0.051	5.21***	−0.363	−0.01	0.089	8.43***
Miles refund/redeem (unit: 10,000 km)	−0.101	−5.13***	0.165	3.77***	0.208	4.22***	−0.025	−1.01	−0.175	−0.03	−0.087	−2.94***
Billing cost (unit: 10 NT$)	−0.038	−4.75***	−0.021	−7.08***	−0.012	−0.91	−0.016	−2.59***	0.005	0.29	−0.011	−2.36***
Segmentation constants	1.081	7.51***	1.160	10.16***	−0.698	−5.19***	0.367	2.63***	−0.074	−0.46	Base value	–
Group market share		29.5%		31.9%		5.0%		14.4%		9.3%		10.0%
Convergence likelihood value: $LL(\beta)$												−15560.48
$\rho^2(\rho_c^2)$												0.46(0.40)
Samples (respondents)												20,700 (6900)

Note: The inertia variable was expressed as actual behaviour → adoption behaviour.
* *P*-value < 0.1.
** *P*-value < 0.05.
*** *P*-value < 0.01.

4.3. Market segmentation and marketing strategy analysis

In summarising and analysing the estimation results of the model, the chi-square tests of the socio-economic and travel characteristics of each group, and ANOVA analysis, the variables and preferences influencing the distance-based ETC system in each segment were sorted. Different groups were then characterised and given appropriate marketing synonyms. The segmentation characteristics are shown in Table 9.

Table 10 shows the elasticity analysis of ETC adoption behaviours. A value greater than 1 in this analysis indicates elastic. While taking both the various marketing strategies and the preference of each group into account, the results of elasticity show that the marketing strategy of using "purchase price" could attract the largest number of groups, including groups 2, 4 and 6 for the GPS e-pass. The reason may be that after the distance-based ETC system was put into practice, freeway users were more willing to adopt the new GPS e-pass product. Decreasing the purchase price of the new product could increase the adoption rate of the GPS e-pass.

4.4. Sensitivity analysis

4.4.1. Purchase price

With all other conditions fixed, this study proposed five pricing intervals for traditional e-pass (from NT$1000 to NT$0), GPS e-pass (NT$6000–NT$0) to determine the change in adoption probability for the two alternatives. Table 11 compares the

Table 9
Users' characteristics of each market segmentation.

Segmentation	Preferred alternative	Influencing variables	Description
Group 1: Frequent freeway users	Traditional e-pass	• Miles refund/redeem • Billing cost	Age, income, and level of education in this group were slightly below the overall averages. This group has the highest usage frequency among groups. The proportion of business leaders was relatively high
Group 2: Retired users	End-of-month billing plan	• Purchase price • Billing cost	The oldest age group among groups, with the lowest education level and income among the six groups. The monthly usage frequency was also lower than that of the other five groups. The proportion of drivers with "no employment" was relatively high
Group 3: Frequent freeway users in the high-tech field	GPS e-pass	• Purchase price • Toll discount	The educational level, income, and usage frequency of this group were all slightly higher than the averages. This group was relatively younger in age than the overall average age.
Group 4: Highly educated users	Experiential marketing plan	• Purchase price • Toll discount • Billing cost	Age and usage frequency were slightly lower than the overall averages, while education level and income were higher than the overall averages
Group 5: High-ranking employees	Experiential marketing plan	No	This group was the second youngest of the six groups. The education level, income, and usage frequency were all significantly higher than those of the other 5 groups. The proportion of executives was relatively high
Group 6: White-collar workers	None	All of the above	Educational level, income, and usage frequency were higher than the overall averages. This group was the youngest of the six groups, and the proportion of staff was relatively high

Table 10
Elasticity analysis of ETC adoption.

Models		LCM							MNL
Alternatives	Marketing strategies	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Weighted	Overall
Traditional e-pass	Purchase price	–	−0.22	−0.34	−0.16	–	−0.08	−0.11	−0.05
	Toll discount	*−0.05*	–	0.64	0.77	–	0.39	0.13	0.09
	Miles refund/redeem	−0.03	*0.73*	*1.14*	–	–	−0.08	0.28	–
GPS e-pass	Purchase price	−0.43	−1.77	−0.40	−1.26	–	−1.11	−0.89	−0.60
	Toll discount	*−0.58*	–	0.07	0.91	–	1.11	−0.04	0.16
Experiential marketing plan	Miles refund/redeem	−0.09	*0.15*	*0.18*	–	–	−0.07	0.03	–
End-of-month billing plan	Billing cost	−1.32	−0.08	–	−0.71	–	−0.50	−0.52	−0.14

Note: – indicates insignificant variables; italic values indicate that the sign was not in line with expectations.

Table 11
Traditional e-pass purchase price scenarios.

Alternatives	Purchase price (NT$)	Toll discount	Billing cost (NT$/month)	Miles refund/redeem
Traditional e-pass	1000 → 0	5%	–	None
GPS e-pass	6000 → 0	5%	–	None
Experiential marketing plan	–	–	–	10,000 km
End-of-month billing plan	–	–	35	None

Table 12
Adoption probability for traditional e-pass.

Purchase cost (NT$)	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 5 (%)	Group 6 (%)	Average
1000	91.8	5.3	7.7	12.0	0.0	39.6	34.8
800	91.9	5.5	8.3	12.3	0.0	40.6	35.0
600	92.0	5.8	8.9	12.5	0.0	41.6	35.3
400	92.0	6.0	9.6	12.8	0.0	42.5	35.6
200	92.1	6.3	10.3	13.1	0.0	43.5	35.9
0	92.2	6.6	11.0	13.3	0.0	44.5	36.2
Change in magnitude	0.4	1.3	3.3	1.3	0.0	4.9	1.4

Table 13
Adoption probability for GPS e-pass.

Purchase cost (NT$)	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 5 (%)	Group 6 (%)	Average (%)
6000	2.3	0.4	71.4	2.8	0.9	16.1	6.4
4800	2.5	0.5	80.2	3.4	1.2	20.1	7.5
3600	2.7	0.7	86.8	4.1	1.8	24.8	8.6
2400	2.9	1.0	91.5	5.0	2.5	30.1	9.7
1200	3.1	1.4	94.6	6.1	3.6	36.1	10.9
0	3.3	1.9	96.6	7.3	4.9	42.5	12.1
Change in magnitude	1.0	1.5	25.2	4.5	4.0	26.4	5.7

purchase price scenarios for the traditional and GPS e-pass, with results of sensitivity analysis presented in Tables 12 and 13. The results indicated that the six groups were not sensitive to changes in purchase price for traditional e-pass, and thus this strategy had no significant effect on the e-Pass utilization rate. In addition, the purchase price of GPS e-pass clearly showed a significant increase in magnitude in Group 3 and Group 6. Reduction in the purchase price was associated with an increased adoption probability for the GPS e-pass in these two groups. The influence of the purchase price on the other four groups was not significant.

4.4.2. Toll discount

Tables 14–16 presents the toll discount scenarios. Trips are billed according to mileage on a pay-by-used basis to determine toll discounts. With all other conditions fixed, toll discounts are presented in five increments from 0% to 100% to observe changes in the adoption probability between the two alternatives. In addition, the estimated results for Groups 1 and 5 did not meet the expectations statistically of the model and are thus excluded from consideration. The results show that Groups 3, 4 and 6 are more influenced by discounts in the traditional e-pass. In particular, Group 6 had a 100% adoption rate when the toll discount reached 100%. However, four groups showed no change in adoption probability in response to discounted GPS e-pass tolls.

4.4.3. Billing cost

The alternative to the three proposed approaches is monthly billing through the mailing on monthly statements which will incur a processing cost. With other conditions fixed, the billing cost was presented in five increments from NT$100

Table 14
Toll discount scenarios for traditional e-pass and GPS e-pass.

Alternative	Purchase price (NT$)	Toll discount	Billing cost (NT$/month)	Miles refund/redeem
Traditional e-Pass	1000	0% → 100%	–	None
GPS-e-pass	6000	0% → 100%	–	None
Experiential marketing plan	–	–	–	10,000 km
End-of-month billing plan	–	–	35	None

Table 15
Traditional e-pass adoption probability with toll discounts.

Toll discount (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 6 (%)	Average (%)
0	5.0	6.5	10.2	30.6	33.53
20	5.9	12.4	18.4	69.3	39.19
40	6.9	22.1	30.5	92.8	44.12
60	8.0	36.2	48.7	98.7	48.38
80	9.3	53.1	69.9	99.8	52.84
100	10.7	69.5	86.0	100.0	56.47
Change in magnitude	5.7	63.0	75.8	69.4	1.9

Table 16
GPS e-pass adoption probability with toll discounts.

Toll discount (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 6 (%)	Average (%)
0	0.4	71.4	2.8	16.1	6.4
20	0.4	71.4	2.8	16.1	6.4
40	0.4	71.4	2.8	16.1	6.4
60	0.4	71.4	2.8	16.1	6.4
80	0.4	71.4	2.8	16.1	6.4
100	0.4	71.4	2.8	16.1	6.4
Change in magnitude	0	0	0	0	0

Table 17
Billing costs and monthly statement scenarios.

Alternatives	Purchase price (NT$)	Toll discount	Billing cost (NT$/month)	Miles refund/redeem
Traditional e-Pass	1000	5%	–	None
GPS e-pass	6000	5%	–	None
Experiential marketing plan	–	–	–	10,000 km
End-of-month billing plan	–	–	100 → 0	None

Table 18
Billing costs and the probability of adopting monthly billing.

Billing cost (NT$)	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 6 (%)	Average (%)
100	0.5	74.0	0.7	1.9	20.8	26.5
80	1.0	80.8	0.8	2.6	24.5	29.3
60	2.0	86.1	1.1	3.6	28.7	31.8
40	4.1	90.2	1.3	4.8	33.2	34.3
20	8.3	93.2	1.7	6.5	38.0	37.2
0	15.9	95.3	2.1	8.7	42.9	41.0
Change in magnitude	15.4	21.3	1.4	6.8	22.1	14.5

to NT$0 to determine the impact on the selection for monthly billing. The estimated coefficient for Group 5 did not match expectations and was thus excluded from consideration. Table 17 shows the scenarios and Table 18 shows the sensitivity analysis results. Table 18 shows that Groups 1, 2 and 6 are significantly influenced by different billing costs, with lower costs influencing those preferring traditional e-pass in Group 1 and the strategic observers in Group 6 to switch preference to monthly billing. In addition, the probability of selecting monthly billing increases in Group 2 as the discount increases.

5. Marketing strategies

According to the previous sensitive analyses on three key factors affecting ETC adoption behaviours, it could be found that drivers in different groups had their own preferences for different ETC alternatives. Undoubtedly, high adoption ratio of traditional e-pass and GPS-pass was the key to the success of this ETC project. Currently, 65% adoption ratio was the target set by the government. When it comes to the implementation of the distance-based toll system, no manual toll collection system remains. At that time, those drivers without equipping e-pass would be tolled through the end-of-month billing plan. Additionally, since billing cost was basically to cover the administration costs for manually checking and bill mailing, it could not be considered as one of tools to promote ETC adoption by adding any extra charge. Accordingly, in what follows, this study only analysed the marketing strategies comprising the discounts in traditional e-pass purchase price and toll rate as well as the financial inputs required for the strategies.

Table 19
Adoption probability for both traditional and GPS e-pass under various combinations of purchase prices and toll discounts.

Purchase price (NT$)	Toll discount					
	0 (%)	20 (%)	40 (%)	60 (%)	80 (%)	100 (%)
1000	38.53	44.19	49.12	53.39	57.84	61.47
800	40.38	46.36	51.56	56.06	60.76	64.59
600	43.33	49.81	55.44	60.31	*65.40*	*69.56*
400	47.88	55.12	61.42	*66.88*	*72.57*	*77.22*
200	53.61	61.82	*68.96*	*75.15*	*81.60*	*86.87*
0	59.25	*68.42*	*76.39*	*83.29*	*90.50*	*96.38*

Note: Italic cells indicate that the adoption probability exceeds 65%.

Table 19 presented the adoption probability for traditional and GPS e-pass under various combinations of purchase prices and toll discounts. A total of 14 combinations could meet the adoption ratio target; that is, the purchase price of a traditional e-pass should be lower than NT$600 and the toll discount rate should be up to 20%. It was worth of noting that Taiwan ETC system was a BOT project and Far Eastern ETC (FETC) company was commissioned to install and operate the system by MOTC (Ministry of Transportation and Communications). FETC collected revenues mainly from e-pass sale and ETC transaction fee (NT$3.4 per entry under the per-entry toll system and NT$0.03554/km under the distance-based toll system), while toll rate was determined by MOTC.

To further compute the financial inputs required for FETC (revenues of e-pass sale and transaction fee) and government (losses in toll revenue) in implementing the corresponding marketing strategies, the following assumptions are made: distance-based toll rate: NT$ 0.82/km, costs of traditional and GPS e-pass NT$680 and NT$4080, respectively.

$$R = K\left(\sum_{t=1}^{T}\sum_{g=1}^{6}\frac{\alpha\left(\mathrm{Pr}_g^T+\mathrm{Pr}_g^G\right)F_g\times L_g\times 12}{(1+r)^t}\right)+Q\left(\sum_{g=1}^{6}\left(\mathrm{Pr}_g^T(P^T-C^T)+\mathrm{Pr}_g^G(P^G-C^G)\right)\right) \tag{9}$$

$$L = K\left(\sum_{t=1}^{T}\sum_{g=1}^{6}\frac{\left(\mathrm{Pr}_g^T+\mathrm{Pr}_g^G\right)F_g\times L_g\times D\times 12}{(1+r)^t}\right) \tag{10}$$

where R was the total discounted revenue of FETC including the transaction fee and e-pass sale (both traditional and GPS e-pass) during the analytical period (years). L was the total discounted losses in toll revenue due to the toll discount during the analytical period (years). K was the yearly freeway on-ramp traffic (vehicles). Q was the total motor vehicles in Taiwan. Pr_g^T and Pr_g^G were the adoption ratios of traditional and GPS e-pass of drivers in Group g, respectively. F_g was the monthly frequency in using freeway of drivers in Group g. L_g was the average freeway travelled distance of drivers in Group g. P^T and P^G were the purchase prices of traditional and GPS e-pass, respectively, while P^G = NT$6000 (i.e. no discount for GPS e-pass). C^T and C^G were the costs of traditional and GPS e-pass, respectively, while C^T = NT$680 and C^G = NT$4080. α was the transaction fee (NT$/km). α = NT$0.03554. D was the toll discount. For discount rate of 20%, D = NT$0.164. T was the analytical period and T = 15 years in this study. r was the discounted rate, which was set as 0.05.

The financial analyses on two out of abovementioned 14 marketing strategies with adoption ratio exceeding 65% were conducted, which were Strategy 1: purchase price = NT$0 and toll discount = 20% and Strategy 2: purchase price = NT$600 and toll discount = 80%. Computation results were shown in Table 20. As noted in Table 20, the transaction fee revenues of FETC were almost the same under two strategies due to the similar adoption ratios (i.e. 68.42% and 65.40%), but the e-pass sale revenues of FETC were remarkably different. under Strategy 1, FETC would suffer from a serious loss of NT$2124.3 millions by offering free traditional e-pass; in contrast, FETC earned a positive revenue of NT$537.9 millions from traditional and GPS e-pass sale under Strategy 2. Even so, during the analytical period of 15 years, FETC still collected a total of NT$4694.2 millions and NT$7185.9 millions under Strategy 1 and Strategy 2, respectively. However, if Strategy 2 was adopted, MOTC would suffer a serious loss in toll revenue of NT$122709.5 millions, which was approximately four times of losses in toll revenue, if Strategy 1 was adopted instead. In comparing to the total investment and maintenance costs of ETC system (approximately NT$3100 millions), Strategy 1 was obviously the best strategy which could reach the target adoption ratio without causing serious losses in toll revenue of MOTC and financial deficit of FETC.

Table 20
Revenues and losses of FETC and MOTC under two strategies (in millions).

Party	Revenues/losses	Strategy 1 (P^T = 0, D = NT$0.2)	Strategy 2 (P^T = NT$600, D = NT$0.8)
FETC	Transaction fee	6818.5	6648.0
	E-pass sale	−2124.3	537.9
	Sub-total	4694.2	7185.9
MOTC	Losses in toll revenue	−31464.0	−122709.5

6. Conclusions

The contributions of the paper to the literature were to study the adoption behaviours of motorists of private passenger vehicles for the freeway ETC system by using discrete choice models through a large-scale questionnaire survey. Especially, to acknowledge the heterogeneity of the ETC adoption behaviours of freeway users, the LCM model was used to establish market segmentation to understand the preference heterogeneity and the key variables influencing drivers' preferences. Data from drivers of private passenger vehicles in 23 counties and cities in Taiwan were empirically analysed, and the optimal model derived from the estimation was then used as the basis to perform additional strategy simulations and analysis of the key variables. The effective marketing strategies were eventually summarised to provide a reference for government officials and the ETC Company aiming to increase e-pass adoption. These results lead us to provide the following main conclusions and suggestions.

The estimation results of the MNL model demonstrated that most variables had significant effects, but the explanatory power of the model was low. The estimation results of the LCM showed that six was the optimal number of groups. In terms of the variables influencing each segment of the distance-based ETC system, Group 1 preferred the traditional e-pass and was influenced by "miles refund/redeem" and the billing cost. Group 2 preferred the end-of-month billing plan and attached importance to the purchase price and billing cost. Group 3 was the GPS e-pass preference group and was oriented towards purchase price and toll discount. Group 4 preferred the experiential marketing plan and attached importance to the purchase price, billing cost, and toll discount. Group 5 also preferred the experiential marketing plan and was not influenced by a combination of marketing strategies. Group 6 considered all marketing strategies. In addition, the sensitivity analysis re-confirms that purchase cost, toll discounts and billing cost had significant impacts on the adoption behaviour of different groups of motorists of passenger cars for the freeway ETC system. At last, in order to achieve the target adoption ratio of 65%, various combinations of purchase prices and toll discounts along with corresponding financial inputs from ETC Company and the government were analysed and suggested.

Some directions for future studies could be identified. Firstly, to further consider others latent variables affecting ETC adoption, such as ease of use, usefulness, risk, reliability, service quality, a discrete choice model with latent variables (e.g. Ben-Akiva and Boccara, 1995) deserved to be developed. Secondly, future research should be conducted using an integrated model with more significant segmentation variables. Last but not least, the model combining choice behaviours of ETC adoption and route choice under the distance-based toll system also worth to attempt.

References

Ben-Akiva, M., Boccara, B., 1995. Discrete choice models with latent choice sets. Int. J. Res. Mark. 12, 9–24.
Bhat, C.R., 1997. An endogenous segmentation mode choice model with an application to intercity travel. Transport. Sci. 31, 34–48.
Bhatnagar, A., Ghose, S., 2004. A latent class segmentation analysis of e-shoppers. J. Bus. Res. 57, 758–767.
Bijmolt, T.H.A., Paas, L.J., Vermunt, J.K., 2004. Country and consumer segmentation: multi-level latent class analysis of financial product ownership. Int. J. Res. Mark. 21, 323–340.
Chen, C.D., Fan, Y.W., Farn, C.K., 2007. Predicting electronic toll collection service adoption: an integration of the technology acceptance model and the theory of planned behavior. Transport Res. Part C 15, 300–311.
Greene, W.H., Hensher, D.A., 2003. A latent class model for discrete choice analysis: contrasts with mixed logit. Transport Res. Part B 37, 681–698.
Holguín-Veras, J., Preziosi, M., 2010. Behavioral investigation on the factors that determine adoption of an electronic toll collection system: Passenger car users. Transport Res. Part C 19, 498–509.
Jou, R.C., Chiou, Y.C., Ke, J.C., 2011. Impacts of impression changes on freeway driver intention to adopt electronic toll collection service. Transport Res. Part C 19, 945–956.
Jou, R.C., Chiou, Y.C., Chen, K.H., Tan, H.I., 2012. Freeway drivers' willingness-to-pay for a distance-based toll rate. Transport Res. Part A 46, 549–559.
Kemperman, A., Timmermans, H., 2009. Influences of the built environment on walking and cycling of latent segments of the aging population. In: Proceedings of the 88th Transportation Research Board Annual Meeting, Washington, DC.
Lazarsfeld, P.F., Henry, N.W., 1968. Latent Structure Analysis. Houghton Mill, Boston.
Smith, W.R., 1956. Product differentiation and market segmentation as alternative marketing strategies. J. Mark. 21, 3–8.
Wen, C.H., Lai, S.C., 2010. Latent class models of international air carrier choice. Transport Res. Part E 46, 211–221.