A MARKET PENETRATION APPROACH FOR THE ESTIMATION OF MARKET POTENTIALS OF FREEWAY ELECTRONIC TOLL COLLECTION SYSTEMS

Shou-Ren HU
Assistant Professor
Department of Transportation Management
Tamkang University
151 Ying-chun Road, Tamsui 251, Taipei County, Taiwan
Fax: +886-2-26221135
E-mail: shouren@mail.tku.edu.tw

Chih-Peng CHU
Associate Professor
Department of Business Management
National Dong Hwa University
Hualien 974, Taiwan
Fax: +886-3-8633010
E-mail: chpchu@mail.ndhu.edu.tw

Abstract: Electronic Toll Collection (ETC) systems have significant benefits for both highway motorists and management agencies. However, there still remains issue regarding the potential market size of the implementation of an ETC system before participating into the investment of an ETC system. Therefore, a systematic scheme for the estimation of the market potentials of an ETC system is one of the crucial issues for various ITS stakeholders to participate into the investment.

In the present research, a systematic scheme based on market penetration approach has been proposed. In the proposed framework, a Fuzzy Delphi method was developed to obtain the possible market penetration rates and volumes at different implementation stages through surveying and consulting local ITS/ETC experts with an expertise rating designation. Preliminary test results show that at a short time period (within 5 years), the market potentials for ETC infrastructure installation were estimated at $0.924 million USD. In the long-term (within 10 years), this number has increased to $1.76 million USD.

Key Words: Electronic Toll Collection, Market Value, Market Penetration, Fuzzy Delphi, ITS Market/Equipment Package

1. INTRODUCTION

Electronic Toll Collection (ETC) systems have significant benefits for both highway motorists and management agencies. A well planned and implemented ETC system provides road users with efficient and user friendly toll payment services without stopping them in front of toll gates, which in turn saves travel times and costs, and results in decreasing of air pollution and fuel consumption. In addition, ETC systems can reduce operational costs by transferring manual toll collection to automatic means. Besides the beneficial properties

stated above, from the supply side of a cashless toll road system, various ITS/ETC venders and system providers in the public and private sectors are keen to know the potential market size of the implementation of an ETC system. From the perspective of cost and effectiveness, these investors are pursuing a systematic mechanism to evaluate if relevant returns can justify corresponding ETC monetary invests. Therefore, an urgent need called for a systematic scheme to estimate the market potentials of an ETC system is one of the crucial issues for various ITS stakeholders in participating into the investment.

In the present research, a systematic scheme based on market penetration approach has been proposed. The expected market size of an ETC system is estimated through the evaluation of numerous ITS market packages and the corresponding equipment packages related to an ETC system. To obtain the possible market penetration rates and volumes at different implementation stages of an ETC project, a Fuzzy Delphi method was developed and numerical practices were conducted by surveying and consulting local ITS/ETC experts with an expertise rating designation. Numerical evaluation for the market potentials of an ETC system was conducted based on a local freeway ETC test project. Preliminary test results show that at a short time period (within 5 years), the market potentials for ETC infrastructure installation were estimated at $0.924 million USD. In the long-term (within 10 years), this number has increased to $1.76 million USD. These outcomes suggest that the implementation of an ETC system is generally worthy of monetary investment to different ITS stakeholders. More importantly, it is helpful to provide those who are interested in the investment of an ETC system with a clear picture of potential market values.

2. PROBLEM STATEMENT AND LITERATURE SEARCH

The market potential of an ETC system is estimated through the relevant automation process/services and equipments/facilities at toll stations and processing centers. In general, ETC systems are substitute for the manually operated tollbooths that are commonly used in congested roads across the nation. In order to use an ETC system, vehicles are equipped with an electronic tag that emits signals to a receiver located at the toll collection facility. The toll amount is automatically deducted from a pre-paid credit balance on a person's account. Therefore, the "market" is defined as a financial services market where a private vendor may offer to undertake the toll collection through a specialized value-added service (such as auditing) to a toll authority in return for a transition fee. The fee may either be a fixed amount per toll usage or some percentage of the total toll revenue generated in a given month or year (ITS America, 1997). Note that the above definition for an ETC market is more private sector oriented. In capturing the overall potentials of an ETC market, the hardware (e.g., electronic tags in vehicles and receivers at toll booths) required for ETC systems are generally provided by the public sector, and are included in the basic ITS services

or ITS infrastructure market. Since an ETC system involves information, computing, mechanical, communication, and other advanced technologies and bill services, therefore, to estimate the potential market size of an ETC system, it is best to investigate the values of its subcomponents such as market packages and equipment packages. By systemically breaking down an ETC system into its subsystems, it is easy to obtain their unit costs and market bases, and avoid the risk of double counting the values of different ITS/ETC functions and/or services.

ETC systems have been widely employed in land transport. To capture the overall market values of an ETC system, one should consider its applications to various transport modes. However, advanced ticketing and billing systems in air and maritime transport have been deployed for a long way. The applications of advanced tolling systems to land transport have just begun for a decade, and it is an issue to be investigated. Therefore, the research scope of the present research is focusing on the market potentials of an ETC subsystem in land transport.

Concerning the estimate of the market potential of an ETC system, current studies include: 1) definition and scope of ITS/ETC market value, 2) evaluation methods, and 3) quantified empirical results.

As regard to evaluation methods, Hu *et al*. (2001) has proposed a Fuzzy Delphi method to obtain the potential market sizes of various ITS Subsystems, in which the total market values are directly estimated through surveying and consulting local ITS/ETC experts with an expertise rating designation at different future time horizons. The issues of market penetration and interdependencies were not captured so that the estimated results were to be further validated based on more real world data. Hu *et al*. (2002) have also presented a Benefit and Cost Ratio (B/C Ratio) method to evaluate the economic effects of ETC from different ITS stakeholders' perspective. Gillen *et al*. (1999) proposed a net-benefit approach to evaluate the cost-and-benefit of ETC investment from various ITS stakeholders' perspectives. Schramm (1997) compared capital cost and operational cost of toll roads with manual and automatic toll collection means. In terms of initial cost, he found that an electronic toll point on a highway with three ETC lanes in each direction typically costs $ 1 million U.S. dollars, or one-third the conventional plaza. Moreover, cashless toll roads provide numerous operational advantages that generate considerable savings in long-term management costs. Starsman and Irion (1998) addressed issues on productivity in terms of measured affects on toll operating expanses, air emissions, and throughput or road capacity achievable. Furthermore, they evaluated the attempts at privatization of toll collection facilities in the U.S. for their cost effectiveness.

3. METHODOLOGY

The method employed in the present research is the Market Penetration method by incorporating a Fuzzy Delphi approach into the integrated methodology. The following section briefly discusses the Market Penetration method with Delphi designation.

3.1 The Market Penetration Method

According to ITS America (1997), the market value of a specific ITS system or service can be estimated through the market penetration method under the assumption of a stable market penetration process. The basic inputs, either obtaining from questionnaire surveys or field investigation, to the proposed method include the following three variables (ITS America, 1997):

(1) *Target Market Base*: the market base that can be targeted potentially by providers of the ITS product or service. For example, the market base for in-vehicle systems could either be the total number of registered vehicles, the projected number of new car sales, or both, if the product accommodates retrofits.

(2) *Penetration Rate*: the degree to which the vendor can capture the target market base for the products or services offered. For example, a five percent market penetration suggests that five out every 100 potential customers are willing to pay for a particular product or service. Market penetration rates change over time, depending on a range of factors such as price, perceived value, and technology trends.

(3) *Price*: the cost of the product to the customer or end-user. This may be adjusted; for example, as has been the case in all technology markets, the prices of most ITS products and services are expected to continue to fall.

The market size is a product of the unit volume (derived by multiplying the target base by penetration rate) and the price. Moreover, the market analysis models can be modified as new information becomes available.

3.2 The Fuzzy Delphi Method

Helmer and Dalkey proposed the Delphi method for long-term forecasting in 1960's and the method has been widely used in various areas to date. Through the process of the Delphi method, anonymous expert talents are pooled to avoid individual domination, and by the iterations of feedback, the expert talents are converged to an acceptable result. However, the more of the iteration process, the more cost and longer survey time it induces. Therefore, alternatively, Murray *et al*. (1985) incorporated Fuzzy measurement into Delphi methods and proposed the Fuzzy Delphi method. Kaufmann and Gupta (1988) used triangular fuzzy number to present the pessimistic, moderate, and optimistic estimation of experts' forecasting to process the Fuzzy Delphi method. Chang *et al*. (1995) applied Kaufman's method to large scale project evaluation problem. Ishikawa *et al*. (1993) proposed the Max-Min Fuzzy Delphi method and the Fuzzy Delphi method via Fuzzy Integration and found these two

methods could reduce the number of repetition of the survey, conduct a more rational forecasting process, and lessen in both time and costs.

In the present research, the Fuzzy Delphi method has been employed to estimate the potential market bases and penetration rates of an ETC system at different time horizons. Specifically, a group of experts at various disciplines were consulted and questionnaire surveys were conducted to collect relevant data required in implementing the Market Penetration method. Based on the analysis of the market penetration approach, the data collected through the Delphi method and surveys include: 1) the maximum and minimum volumes of each ITS/ETC market package and equipment package, 2) possible market penetration rates for each ITS/ETC market package and equipment package, and 3) self-evaluation expertise score for each question item. By obtaining the data based on the multi-runs of the proposed method, one can predict the potential market sizes of an ETC system at different development time periods through the following 4 steps:

Step 1: establish a membership function. A group of n experts is desired to give an interval-valued opinion on each survey item to form a set of triangular fuzzy number, $\left(h(u_1), h(u_2), h(u_3), .., h(u_n)\right)$.

Step 2: sort the membership function value, and rearrange the membership function associated with expert confident index by the value in descending order, $\left(h(u_1), h(u_2), h(u_3), h(u_4)\right)$ and $\left(g_1, g_2, g_3, g_4\right)$.

Step 3: calculate the Fuzzy integration value, μ, the formulation of μ is:

$$\mu = \int h_i \circ H_i = \bigvee_{i=1}^{n} [h_i \wedge H_i] \tag{1}$$

where $H(u)$ is:

$$(1)\ H(u_1) = g_1$$

$$(2)\ H(u_i) = H(u_{i-1}) + g_i, \quad 2 \le i \le n$$

Step 4: find the forecast value X^* as follows:

$$X^* \text{ (forecast value)} = \max.(\mu) \tag{2}$$

4. EMPIRICAL STUDIES

To demonstrate the feasibility of the proposed framework, the present section details the empirical studies based on a local test ETC project. The section includes data description, questionnaire surveys, and estimation results.

4.1 Data Description

The market values of ITS/ETC systems are estimated under the basis of corresponding Market Package (MP) and Equipment Package (EP). Since MPs and EPs are the basic components of their respective ITS systems and/or services, therefore these end products or services are easily obtained and purchased in the market. More significantly, the unit costs

and sale volumes of the MPs and EPs can be objectively estimated through market research and updated periodically once new products and/or services are available.

In the present empirical studies, the Market Package of an ETC system is categorized into ATMS 10, according to ITS America's study (1997), or the ETC subsystem. The ETC subsystem is further divided into 3 EPs: (1) Fleet Management, (2) Fare Management, and (3) Toll Collection. The unit costs for each of the three EPs of an ETC subsystem are referring to the ITS Unit Costs Database provided and maintained by the U.S. DOT and ITS America (2001). Finally, the time horizons of the estimation are defined as short-term in 5 years and long-term in 10 years.

4.2 Questionnaire Surveys

To obtain the relevant parameters in conducting the market penetration approach, a two-run Fuzzy Delphi method was employed. Specially, a group of 15 experts were consulting and relevant data were collected with the designation of a self-evaluation expertise score in view of the different areas of specialization. The score ranges from 0 to 10 representing "completely unknown" and "fully understanding", respectively. With the specific designation, we may collect more realistic responses about relevant model parameters required in the market penetration based models.

In the questionnaire, besides collecting each individual's background information, each expert at various professional areas is asked, based on a local ETC test project, their personal views on the following items: 1) the market penetration rates, 2) the saturated and potential market demands, and 3) expertise scores for each EP of the ETC subsystem at different time periods. Question items on both market penetration rates and potential market demands are designed to obtain the maximum and minimum quantities in order to acquire the upper and lower bounds needed in the Fuzzy based model.

Since an ETC system involves information, computing, mechanical, communication, and bill services, therefore, the 15 experts were selected from different domains of expertise. They are professionals in the areas of traffic engineering, information and communications, highway administration, banking services, and market research. Tables 1 through 3 present the relevant data collected in the first run of the survey using the Fuzzy Delphi method. As shown in tables 1 through 3, since the estimation results of a few respondents are significantly different from those of the average levels, therefore they are excluded from the analysis. Moreover, the estimated demand for each EP is obtained by conducting the Fuzzy approach. Finally, the market value is obtained by multiplying the estimated demand and unit cost of a specific EP, and sums up all the estimated market values of the three Eps, resulting in the final estimation of an ETC subsystem.

Table 1. Results of the First-run Survey on Fleet Management (short-term)

ATMS10. Electronic Toll Collection Subsystem						
(1) Equipment Package: *Fleet Management*						
5 Years	Penetration Rate (%)		Saturated Demand (set)	Potential Demand (set)		Expertise Score
Respondent	Min.	Max.		Min.	Max.	
A	10%	15%	280	28	42	6
B	10%	30%	50	5	15	8
C	5%	15%	200	10	30	6
D	10%	30%	200	20	60	5
E	20%	30%	15	3	4.5	8
F	30%	50%	15	4.5	7.5	5
G	20%	30%	60	12	18	5
Estimated Demand (set)						15
Unit Price ($1,000 USD)						$12.5
Market Value ($USD)						$187,500

Table 2. Results of the First-run Survey on Fare Management (short-term)

ATMS10. Electronic Toll Collection Subsystem						
(2) Equipment Package: *Fare Management*						
5 Years	Penetration Rate (%)		Saturated Demand (set)	Potential Demand (set)		Expertise Score
Respondent	Min.	Max.		Min.	Max.	
A	10%	50%	30	3	15	7
B	0%	10%	200	0	20	4
C	30%	50%	20	6	10	5
D	5%	10%	1000	50	100	5
E	25%	35%	100	25	35	9
F	0%	30%	100	0	30	4
G	20%	30%	60	12	18	5
H	10%	20%	1000	100	200	2
Estimated Demand (set)						15
Unit Price ($1,000 USD)						$12.5
Market Value ($USD)						$187,500

Table 3. Results of the First-run Survey on Toll Collection (short-term)

ATMS10. Electronic Toll Collection Subsystem						
(3) Equipment Package: *Toll Collection*						
5 Years	Penetration Rate (%)		Saturated Demand (set)	Potential Demand (set)		Expertise Score
Respondent	Min.	Max.		Min.	Max.	
A	0%	50%	50	0	25	8
B	40%	75%	20	8	15	5
C	10%	30%	500	50	150	7
D	10%	70%	20	2	14	5
E	90%	95%	300	270	285	9
F	0%	30%	100	0	30	7
G	50%	70%	150	75	105	6
H	20%	30%	60	12	18	5
I	20%	30%	1000	200	300	4
J	2%	4%	6000	120	240	4
Estimated Demand (set)						275
Unit Price ($1,000 USD)						$3.5
Market Value ($USD)						$962,500

4.3 Estimation Results

By providing the estimation results to the respondents in the first run of the survey, the answers replied by the same respondents in the second run might partially refer to the results of the average levels in the first run of the survey. In such a way, data convergence is possibly achieved. Furthermore, by conducting the 2-run questionnaire surveys using the Fuzzy Delphi approach, the potential market sizes at different time horizons, based on a local ETC test project, were available, and shown in table 4. The market values of the test ETC project were estimated from $0.924 million USD to $1.76 million USD at the short-term and long-term time periods, respectively. The preliminary estimation results provide various ITS/ETC stakeholders, both in domestic and international platforms, with a clear market sizes in the participation of an ETC project.

Table 4. Market Values of ETC Subsystem at Different Time Periods

EPs for ETC Subsystem	Short-term ($USD)	Long-term ($USD)
(1) Fleet Management	187,500	275,000
(2) Fare Management	106,250	225,000
(3) Toll Collection	630,000	1,260,000
Total	923,750	1,760,000

5. CONCLUSIONS AND RECOMMENDATIONS

In the present paper, a systematic scheme based on the market penetration approach has been proposed. The expected market size of an ETC system is estimated through the evaluation of numerous ITS market packages and the corresponding equipment packages related to an ETC system. To obtain the possible market penetration rates at different implementation stages of an ETC project, a Fuzzy Delphi method was developed and numerical studies were conducted by surveying and consulting local ITS/ETC experts with an expertise rating designation. The numerical results based on a local freeway ETC test project provide various ITS/ETC stakeholders, both in domestic and international platforms, with a clear market sizes in the participation of an ETC project.

The present paper has proposed a desirable framework for the estimation of market sizes of ITS subsystems. However, the unit costs for ITS market packages and equipment packages may change over time since the innovation and evolution of new ITS products and services become surfaced very rapidly. Therefore, it is suggested to update the unit costs database periodically by referring relevant market surveys and research. Moreover, the portion of public investment on infrastructure of ITS or ETC subsystems have not yet been accounted in the estimation of total market potentials. The results obtained in the present research might underestimate the total market value of an ETC system. This is another crucial issue worthy of future investigation.

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