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Abstract: The past decade has witnessed an increased application for dynamic pricing in transportation industry, where firms use various forms of dynamic pricing to respond to market fluctuations and uncertainty in demand. In light of the success in the airline dynamic pricing practice and given the advancement of the ICT technology, the question is raised as follows: can technology adoptions, such as smart card, help the transportation companies, especially public transport operators, to approach the dynamic pricing in an innovative way? By using the case of the smart card adoption in the Dutch transportation industry, this article articulates the opportunities the smart card brings to the dynamic pricing design and use. It is demonstrated that the smart card data gives a dimensional view on the travellers, where both the market segmentation and the travel behaviour could be better studied. It is also argued that the rich segmentation information on the travellers and the increased understanding of the travel behaviour could lead to the level of refinement of the dynamic pricing strategies for the transportation companies. Furthermore, a number of dynamic pricing strategies are proposed that correspond to the discussed smart card dimensions.

Keywords: Emerging technology, case study, smart card, dynamic pricing.

I. Introduction

The past decade has witnessed an increased application for dynamic pricing in transportation industry, where firms use various forms of dynamic pricing to respond to market fluctuations and uncertainty in demand. One particular example is the dynamic pricing strategy used in the budget airlines (some examples are easyJet and Ryanair in Europe and jetBlue in the U.S.). These airlines typically offer only one type of ticket on each flight, a non-refundable, one-way fare without advance-purchase restrictions. However, they offer these tickets at different prices for different flights, and moreover, during the booking period for each flight, vary prices dynamically based on capacity and demand for that specific departure [16].

The other transportation companies, especially public transport operators (PTOs), however, are in the dilemma and having difficulties in fully taking advantage of the dynamic pricing. On one hand, there is a definite need. Transportation planners and public transport operators alike have become increasingly aware of the need to diffuse the concentration of the peak period travel. Dynamic pricing is argued as one of the most preferred revenue management method [16] to both reduce the peak travel requirement and increase the capacity utilization. And on the other hand, there is a practical limitation. Without deploying booking and reservation system as the airlines do, PTOs are not able to manage the variable demand of the heterogeneous travelers and spread them over the course of the day or the week.

At the same time, the rapid development of information communication technologies (ICT) and the expansion of the Internet have deeply affected the way in which various transport operators deploy and exploit their products and services in the transportation marketplace [6]. The advent of the emerging transportation ICT technologies, such as automatic vehicle location and tracking (AVLT), automatic data collection (ADC) and automatic fare collection (AFC), from the travelers' perspective, has provided enormous travelers' transit information (i.e., real-time traffic information) and enhance the quality of their travel experience. From the transport operators' perspective, they are striving to adapt their business processes to take advantage of the possibilities that these emerging technologies offer.

In light of the success in the airline dynamic pricing practice and given the advancement of the ICT technology, can PTOs be inspired to get out of the dilemma? Specifically, will the transportation ICT technology help the PTOs to approach the dynamic pricing in an innovative way? Unfortunately we are still a long way from fully understanding the possibilities as we have only begun to recognize the potential of these transportation ICT technologies. Before we can design the strategy (i.e., dynamic pricing) to take maximum advantage of the new and emerging technologies, we need to have a clear picture of what such emerging technology could offer. The answers to the above questions are sought in a case study approach. By using the case of the smart card adoption in the Dutch transportation industry, this article offers a contribution by outlining several dimensions of the smart card attributes along which a number of pricing strategies are proposed.

The reminder of the article is organized as follows. The article starts with a review on the existing literature on ICT adoption and dynamic pricing. These two theories are developed into a conceptual framework. Next, an explanation of the empirical setting in the smart card adoption in the Dutch transportation industry is given,

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together with research method and data. This section is then followed by presenting the empirical analysis, which emphasises on the smart card attribute dimensions and the innovative pricing strategies that linked to each dimension. The article ends with conclusions and suggestions for further research.

II. Literature Review and Conceptual Framework

This section discusses dynamic pricing and ICT operational adoption, which appear to be essential for this article. These two theories are then developed into a conceptual framework.

II. 1 Dynamic Pricing in the Transportation Industry

Dynamic pricing can be formally defined as the selling of goods in markets where prices move quickly in response to supply and demand fluctuations. Charging different prices for the same product is price discrimination [5]. One type of price discrimination, second price discrimination, is based on identifying the willingness to pay of different groups of customers through their purchasing behaviour. Economic theory argues that dynamically changing prices is inherently good for the profitability of the firm, because it allows the firm to capture a larger share of the consumer surplus. Consumer surplus is viewed as the difference in the price that the customers are willing to pay and the actual price that they end up paying. Price discrimination moves some of the customer surplus to the suppliers.

It has long been the tradition of transportation companies, especially airlines, to use the flexible pricing strategies to manage their perishable inventory efficiently. Argued by Boyer [5], transportation companies are in an especially good position to engage in price discrimination. This is mainly because that it is generally possible for the transportation companies to satisfy the characteristics that are common to the applications of the dynamic pricing [12]. These characteristics include the following: 1) managing relatively fixed and inflexible capacity; 2) the inventories are perishable; 3) existence of variable and uncertain demand; 4) the customers are heterogeneous, however, could be segmented; 5) the companies have appropriate cost and pricing structure; 6) the data and information system infrastructures are available.

II. 2 ICT Adoption in the Organization

The impact of general ICT adoption in the organization has been extensively studied in the past decades. Three major research streams in regard to the impact on the organizational performance could be identified. 1) Cost reduction. Many researchers have argued that ICT is particularly useful in information-intensive activities, since the use of ICT might lead to the reduction of coordination costs and therefore, decrease transaction costs [10]. 2) Revenue generation. Some authors have investigated how the use of ICT might affect revenue generation in information-intensive activities. For example, Bakos [3] supports the claim that using ICT supports new pricing strategies. 3) Increase flexibility. Some authors have stressed the possibilities of ICT to increased interorganizational flexibility [13,21].

The ICT technologies that are adopted in the transportation industry have been systematically analysed by [9]. Furthermore, their paper also offers a more general view on the impact of the ICT adoption on both personal travel and commercial vehicle operations. In the smart card literature, although there are comprehensive reviews of smart card technology and its commercialisation [15], many of the papers have focused on either technological aspect or the payment aspect [18] of this ICT adoption. Only until recently, the smart card adoption affects on the data collection process have been studied through Bagchi and White [2] empirically examination in the UK bus operation.

Being one type of ICT adoption, smart card based automatic fare collection systems are being introduced all around the world in the transportation companies. Being the first setup, Hong Kong’s “Octopus” card has more than 5 million active users since the adoption in 1996. Singapore’s “EZ-Link” card also reaches a 5 million user base since 1999. Transport for London (TfL) adopts “Oyster” card on its London transport system that covers tube, bus, trams and national rail services, and have attracted 7 million users. The widespread adoptions have undoubtedly exemplified the great interests of PTOs on the smart card technology. Now the question is: are the adoption of the smart card technology in the transportation companies could leverage the opportunity of the dynamic pricing?

II. 3 Conceptual Framework

The following conceptual framework depicts the potential influence that the adoption of smart card in the transportation companies may influence the design and use of the dynamic pricing. Based on the literature review we formulate the following proposition.

Determining the “right” price to charge a customer for a product is a complex task, requiring that a company know not only its own operating costs and availability of supply, but also how much the current customer values the product and what future demand will be [7]. Therefore, to charge a customer the right price, a company must have a wealth of information about its customer base and be able to set and adjust its prices at minimal cost.

The term dynamic pricing is used in this article to broadly encompass tariff structures that adopt differentiated pricing [5], in which different buyers may receive different prices, as opposed to the auction pricing mechanism that has prices and conditions based on bids by market participants [11]. The practical motivation for developing dynamic pricing options can probably be traced to the need to reduce the peak load requirement, the variable and uncertain demand, as well as the profitability of the firm.

Tremendous data could be obtained through the usage of the smart card by the transportation companies. These data can be used to derive the detailed traveler information over the cost that users are willing to undertake. Unlike the traditional time-consuming survey method where the changes are observed slowly because of the information delay, the smart card becomes a powerful tool for almost instantaneous consumer feedback. The key advantage is that it provides a detailed understanding of willingness-to-pay and traveler characteristic information. This should provide more accurate price-demand projections than are attainable via the traditional survey methods. Transportation companies could then design their pricing strategies to separate the higher and lower price segments: to separate the travelers that are sensitive to the price change (recreational traveler) and people that are insensitive (home-work traveler).

The adoption of the smart card in the transportation companies provides 1) increased availability of traveler data, 2) opportunity to change the prices more easily, and 3) potentials to combine with the decision support tools for analyzing the demand data. These improvements allow the PTOs to design and use the dynamic pricing strategies that they are not capable earlier, when the companies had limited ability to track information about their travelers and faced high costs in changing prices [7]. Thus, we have:

Proposition 1: Smart card adoption of the transportation companies leads to the design and use of dynamic pricing.

In light of the smart card adoption in the Netherlands, the PTOs have many questions concerning the impacts of the adoption, including technological, social, environmental, commercial and operational aspects. Because of the limit in space, this article will mainly focus the relationship to the dynamic pricing, which distinguishes itself and also makes an important contribution to the similar research of this kind [1,4,17].

III. Research Context and Research Method

This section elaborates the research context and the research method. The above-mentioned conceptual framework will be studied based on the case of the smart card adoption of the Dutch transportation industry,

III. 1 The Context

The way in which people use public transport in the Netherlands is changing – as it is in cities and countries across the globe. Trans Link Systems (TLS) plans to deliver a seamless ticketing and fare collection system for the complete public transport system throughout the Netherlands. The system will initially be rolled out in Rotterdam in September 2005 and extended to cover the whole country by the end of 2007. Using smart card and readers' technology, this all-encompassing contactless ticketing infrastructure will cover trains, metro, trams and buses – providing travelers with increased convenience and added satisfaction. At full implementation the system will have to contend with an estimated 1.5 billion transactions each year.

III. 2 Research Method and Data

Case study research is chosen to test the proposition as it investigates a contemporary phenomenon within its real-life context [23]. The rationale for selecting the single case - the smart card adoption in the Dutch transportation industry - for is being representative [23]. And at the same time, it satisfies two criteria for the case selection: 1) the smart card technology is being implemented, and 2) different pricing strategies are being considered while the introduction is taking place.

Data was collected through personal interviews, documents, websites and previous researches. Taking the full strength of the case study method, this data collection approach also tries to enhance the validity of the research. In total, 12 interviews were carried out with people from marketing, commercial, research and logistics departments at different management levels in transportation companies as well as public institutions.

IV. Analysis of the Empirical Data

In this section, an empirical analysis of the gathered information will be performed. After presenting the lack of information problem that occurs in the current situation, it demonstrates the dimensional classification of the smart card data attributes. As a result, a number of dynamic pricing strategies for the railway travel are proposed that correspond to the discussed dimensions.

IV. 1 Lack of information in the current situation

There are mainly two ways for the PTOs to gather the travelers' information in the current situation. First, the PTOs would have some records of their frequent travelers who left their details after their purchasing. Second, different surveys are conducted every year or every few years to cover different aspects of the travelers' information. For example, there are surveys that look at the characteristics of the travelers, the frequency of the travel and the preferred time of the travel. However, the questions concerning what type of product their travelers use and when exactly they use it are still largely remain outdated, inaccurate and even unknown.

IV. 2 Smart Card Data Dimensions

Each time the smart card is used, either to make a trip or to purchase/renew a travel product that loaded to the card, details of the trip and/or product made with the card will be captured and linked to that smart card or the individual if the smart card is registered under that individual. The smart card, hence, gives the PTOs the opportunity to capture the behavior of the travelers more easily.

The information extracted from the smart card data consists of the origin and destination of the travel, the travel time at the origin and the destination, and the transport services that the travelers use. The transport services include the mode of the transport and the vehicle type of that particular transport mode. For example, for the train travel, the vehicle type may vary from international train, intercity train, fast train, and slow train. If the smart card is not "transferable", which means only the card holder is allowed to use the card, it may also contain the profile information of the card holder, for example, age, gender, name, address and maybe profession. Privacy concern would be relevant in this context, however, is out of the scope of this article.

The smart card data attributes (depends on the specific implementation) could be classified into five dimensions (see **Table 1**). The categorization is largely based on the smart card data attributes that are presented by Bagchi and White [1]. The categorization gives an indication on how the travelers could be segmented. For example, in the spatial dimension, travelers could be segmented based on different origin-destination route; peak and off-peak period travel segments the travelers in the temp,oral dimension. The five dimensions are:

- *Temporal dimension*: time and date of departure and destination;
- *Spatial dimension*: departure and destination of the travel;
- *Service dimension*: travel mode and vehicle type;
- *Personal dimension*: traveler's name, age, gender, address and profession;
- *Buying dimension*: travel product purchase time/date, location and price;

Table 1: Smart card data attributes and its dimensions (adapted from Bagchi and White, 2004)

Smart Card Attribute	Smart card	Temporal dimension	Spatial dimension	Service dimension	Personal dimension	Buying dimension
Card number	x				x	
Cardholder name and address	x				x	
Cardholder age	x				x	
Cardholder gender	x				x	
Travel origin	x		x			
Travel destination	x		x			
Time / day of departure (origin)	x	x				
Time / day of arrival (destination)	x	x				
Transport mode and vehicle type	x			x		
Product purchase time and date	x					x
Product Purchase location	x					x
Type and price of product	x					x
Travel purpose						

Travel purpose: The travel purposes that are now collected with the travel survey cannot be captured with the smart card.

IV. 3 Dynamic Pricing Strategies

As one of the most important price-based revenue management techniques, dynamic pricing has a direct, and sometimes dramatic, impact on operations and vice versa [8]. Dynamic pricing is one possible method to manage demand and reduce the peak load requirement. In this section, a number of dynamic pricing strategies for the railway travel are proposed that correspond to the previously discussed smart card data dimensions. For each strategies proposed, an explanation on how it works is given together with specific examples on the pricing scheme.

Table 2: Smart card data attribute vs. tariff structure

Smart card data dimension	Dynamic pricing strategy
Temporal dimension	Time-based pricing; (time-of-day; day-of-week)
Spatial dimension	Directional pricing; Regional pricing;
Service dimension	Usage-based pricing; Demand-based pricing;
Personal dimension	Age-based (e.g., 65+); Profession-based (e.g., student);
Buying dimension	Periodic fare product promotion

Temporal dimension: Time-based pricing is by far the most frequently used pricing strategy among all the proposed ones by the transportation companies.

Time-based pricing. In the Netherlands, the morning peak hour is defined as between 7:00-9:00am each weekday. The periods after 9:00am and the weekends are defined as off-peak. In practice, a reduction card is available for the travellers who travel during the off-peak, which gives them a 40% reduction on the travel. This reduction policy is an example of time-based pricing. It is argued that giving discounts to travelers during the uncongested off-peak should attract much less opposition than an extra (punitive) fare on peak-hour travellers [20]. Other example of this time-based pricing strategies are: for the time-of-day strategy, introducing the pre-morning peak (cheaper fares before 7:00am); for the day-of-week strategy, introducing lower weekend fare; There are many time-of-day priced services already in practice, including telephones (cheaper evening and weekend rates), movie theatres (the matinee show) and restaurants (the "early bird" special).

Spatial dimension: Dynamic pricing strategies that are designed by using the spatial dimensional data are: directional pricing and regional pricing.

Directional pricing. Apart from the time-dependence of the travel demand, the directional imbalance, which means unequal demand in both directions, also heavily impacts the load factors of the PTOs. In a normal weekday, the railway operation data shows that during the peak hours the trains are crowded while moving to the direction of the big cities, whereas they may be almost empty on the other direction. In fact, majority of the travelers who travel in the morning peak are the ones who either work or study in the destination city but live in another city. As expected, the dataset for the afternoon peak between 16:00 to 18:00 demonstrates an opposite directional pattern. PTOs can apply several strategies to accommodate this imbalance [14], among one of them, direction-dependent differentiated pricing could be expected to have a positive effect on improving the load factors as well as the profit.

Regional pricing. Similar to the zone-based pricing in some cities for the bus and the metro transport, regional pricing in the rail transport could be thought of as applying different regional tariff to each region. For example, a differentiated price could be charged for the traveling to and from the most important cities in the *Randstad*. (*Randstad* is the metropolitan area in the western part of the Netherlands, including major cities, such as, *Amsterdam*, *Rotterdam*, *The Hague* and *Utrecht*. It has high work availability, many multinational corporations and universities that attract many people to work and study.) Hence, the travel demand of this region is significantly higher than the average demand of the rest of the country. van Vuuren [19] has proved that peak hour seat kilometres on dense tracks are underpriced, both from the profit-maximizing perspective and from the welfare-maximizing perspective. In fact, it has been considered of adding an additional unit of tariff to the current tariff for the people traveling to and/or from *Randstad*. Another option is to reduce the price of travelling in the less populated area, such as the east of the country. To make it even more sophisticated, different prices could be charged for different origin-destination pairs. This is because the trains on some tracks are more crowded than the others.

Service dimension: two innovative pricing strategies, namely, usage-based pricing and demand-based pricing are introduced in this dimension.

Usage-based pricing. For the travel card holders, who have month card, trajectory card, etc., there is no fare charged for the additional travel. Thus extra travels, such as returning home to lunch from work, weekend family visit etc., are "free". An earlier empirical analysis [22] has shown that the travel card has lower price elasticity than the single ticket. This means the travelers that have travel card are less price-sensitive than those of the single ticket. With the introduction of the stored-value-ticket, these travelers who travel more than the average will choose to stay with the travel card. While on the other hand, people who use the travel card less than the average will switch back to the single ticket. In the usage-based pricing scheme, travelers are billed on the actual travel kilometers during any given month. There are a number of options for implementing this usage-based pricing. 1) Pay-as-you-go. Fixed costs are charged for every kilometer a person travels. 2) Contract for fixed amount. A contract is signed between the traveler and the PTOs for a fixed amount of kilometers given a certain price. 3) Product bundle. It is a pricing scheme that consists of a premium and a charge for the additional travel being made.

Demand-based pricing. Assume the travelers' boarding information is captured at virtually real time, the PTOs then know the total demand and consequently the utilization of the transport vehicles. The demand-based pricing proposes to let the tariff vary based on the travel demand. In that case, the PTOs could decide on for example, lowering the prices for the traveler when the total travel demand exceeds certain level or the utilization is higher than a given rate.

Personal dimension: Different travel cards could be designed for people in the different profile group. For example, student travel card or travel card for senior people above 65 years. Some of these are already implemented in practice.

Buying dimension: Periodic promotions to attract new travelers are considered as the pricing strategy that fits into this dimension.

IV. 4 Refined Conceptual Framework

Based on the analysis of the dimensionality of the smart card attributes and the proposed dynamic pricing strategies that map into the dimensions, a refined conceptual framework (see Figure 1) is developed through a set of refined hypotheses.

Hypothesis 1: Smart card adoption in the transportation companies provides rich information on travelers' segmentation.

Customer segmentation is the practice of dividing a customer base into groups of individuals that are similar in specific ways relevant to marketing. Using segmentation allows companies to target customer groups effectively.

The smart card data provides rich information on travelers on the discussed dimensions. These data and/or together with other data sources could then be used to analyze the segmentation of the travelers. There are many ways to segment the market as can be seen from the number of data attributes along different dimensions. Travel purpose is by far the most frequently used segmentation in the transportation industry. Although the data on the travel purpose will still not be possible to obtain by using the smart card, it is generally available via survey method. For example, distinctions could be made between commuters (home-to-work or home-to-study traveler), business (first class traveler), and recreation (holiday or shopping).

Hypothesis 2: Smart card adoption in the transportation companies leads to better understanding of the travel behavior.

Travel behavior research is the study of what people do over space, and how people use transport. The questions studied in travel behaviour are broad, such as, how many trips do people make? Where to they travel to and from? What mode do they use? When is the trip being made? etc. These information are traditionally obtained by using travel surveys. Conducting survey, especially large scale travel behavior survey, requires big efforts and spans long period. Smart card data enhance the ability of the PTOs to know where the people travel to and from, at what time, and at what price. It is important to note that the revealed segmentation information of the travelers is different from understanding the travel behavior. The latter concerns some issues in a broader scope. Besides the ones mentioned, other travel behaviour related questions are: what is the pattern of trips? Would the price increase of the public transport affect the travelers decision making on mode choices? Is the crowdedness an important factor when people making mode choice? Answers to these questions could not be given unless more insights into the behavioural aspects of the travel are gained.

Hypothesis 3: Rich information on the travelers' segmentation leads to the level of refinement of dynamic pricing strategies.

Various empirical analyses have shown that the demand for the train transport during the peak hours is inelastic, while the demand during the off-peak is elastic [19]. According to van Vuuren [19], the motivation plays an important role for this. As the travelers usually do not have many alternatives and therefore cannot easily switch to other modes or another departure time or another track, resulting in relatively low price elasticity for the demand during the peak hours.

Price elasticity is defined as the percentage change in consumption of the good (change in demand) caused by a one-percent change in its monetary price or other characteristics, such as service quality. The gathered data from the smart card and other sources could be used to derive the elasticity information for each traveler segment. As a result of it, transportation companies could tailor their dynamic pricing strategies to different market segments in a more refined level and allocate their marketing resource more effectively.

Hypothesis 4: Better understand the travel behavior leads to the level of refinement of dynamic pricing strategies.

An example of using proposed time-based pricing strategy is to introduce an afternoon-peak (16:00-18:00) price. Instead of paying the off-peak reduction price, travellers that travel during the afternoon-peak would be charged to a higher price. The introduction of this policy is in an effort to even-out the peak travel concentration. Then the question is: would this policy shift the demand of the travelers to a less-crowded period of the day? Or will the travellers change to a different mode of travel? Answers to these travel behaviour related questions would be essential to assess of the pricing policies. And more importantly, it will lead to a more refined level of pricing strategy design.

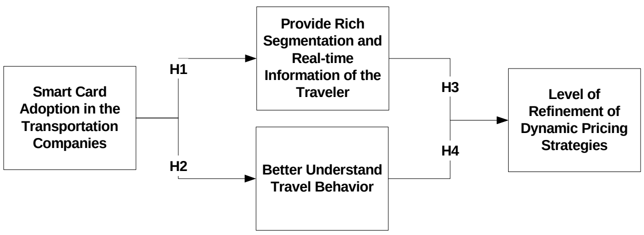

Figure 1: Refined Conceptual Framework

V. Conclusions

Based on the case study result from the Dutch transportation industry, this article argued that the adoption of the smart card by the transportation companies on one hand provides rich segmentation and real-time information of the travelers. And on the other hand, it leads to the ability to better understand the travel behavior. As a result of it, an improvement on the level of refinement for the design and use of the dynamic pricing strategies could be achieved.

There are several suggestions for further research on the relationship between smart card adoption and the design of the dynamic pricing.

First, a number of pricing strategies have been suggested in this article. An evaluation of the potential effectiveness of the strategies needs to be tested.

One of the hypotheses suggests that travel behaviour leads to better pricing design. In order to better design the dynamic pricing strategies, PTOs should first understand their travelers in regard to their travel decisions. Despite the potential of differentiated pricing to ease the peak period public transport demand problems, there is little quantitative evidence of its ability to influence the behavior of the travelers. Therefore, future research could emphasis on answering the questions, such as, how do travelers respond to time-dependent pricing strategy during the day? Are they shifting to a cheaper period or are they paying the higher price?

Third, though the adoption of the smart card in the transportation companies offers tremendous opportunities to design sophisticated dynamic pricing strategies (i.e., individual-level price discrimination), in practice, the pricing structure has to be simple and easy to communicate to the travelers.

Fourth, it is clear that the above proposal on dynamic pricing are based on a rather idealised travel markets and only the transport operators' profit-maximising objective is considered. Travelers may express an objection for crowding, unfairness and fare complexity, which consequently might change their willingness-to-pay. To bring the models closer to reality, the future research could focus on understanding the travelers' behaviour change under the influence of the dynamic pricing, and the cost of complexity.

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