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The Impact of Travel Time Reliability and Perceived Service Quality on Airport Ground Access Mode Choice

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Abstract

This study makes two contributions to existing airport ground access mode choice models. The first is an assessment of travel time reliability on air passenger airport ground access mode choice decisions. Revealed preference questions were asked to determine the safety margin allowed for ground access journey to airports. The larger the safety margin allowances, the less reliable the passenger perceived the mode to be. Stated preference questions were also used to determine the impact of travel time reliability on mode choice decisions. The second contribution of this research is the incorporation of air passenger perceived service quality in the calibration of airport ground access mode choice model. With the use of the survey data, the effects of safety margin allowances, travel time reliability, and perceived service quality on ground access mode choices to Hong Kong International Airport are quantified by a multinomial logit-type mode choice model. For strategic planning, the calibrated model can be used by the airport authority and various transport operators for evaluating the changes in the service attributes on modal split pattern in international airports, hence improving the access mode services.

Keywords: Ground access mode choice, perceived service quality, safety margin, travel time reliability

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1 Introduction

The demand of air transportation increased overwhelmingly in the past decade owing to the economic growth worldwide. Air passenger traffic is expected to keep rising at four percent per year until at least 2020 (Airports Council International 2005). The air traffic expansion has lead to demand overload on airport ground access traffic, and is a subject of growing concern by airport authorities.

In order to facilitate airport ground access planning, the Bay Area Metropolitan Transportation Commission (MTC) has conducted surveys regularly at three international airports in the San Francisco Bay Area, San Francisco International Airport, Oakland International Airport and Norman Y Mineta San Jose International Airport. With the use of the MTC survey data, Harvey (1986) and Pels et al. (2001; 2003) developed discrete choice models to quantify the relative importance of various factors regarding air passenger ground access mode choice decisions. They highlighted that business air passengers are more sensitive to travel time while non-business air passengers are more sensitive to travel cost. Other factors influencing airport ground access mode choices included trip purpose, party size, residential status and the number of pieces of baggage carried by an air passenger (Clark and Lam 1990; Harvey 1986; Shapiro et al. 1996).

Monteiro and Hansen (1996) calibrated both multinomial logit (MNL) and nested logit (NL) models, with 1990 MTC survey data, for analyzing departing air passenger airport-access mode choices. Their model results indicated that ground access mode choice strongly influences the airport choice in a multiple airport region. They contended that rail has a market for accessing the airports in the San Francisco Bay Area, and recommended that the San Francisco Bay Area Rapid Transit (BART) rail system to San Francisco International Airport be extended. Thus increasing the utilization of the BART system and strengthen San Francisco International Airport as the dominant airport in the San Francisco Bay Area. Loo (2008) also applied MNL modeling to identify attributes that affect passengers' airport choice in multiple airport regions. However, based on the stated preference (SP) data collected at Hong Kong International Airport (HKIA), Loo (2008) found that the number of access modes and access cost were not significant on passengers' airport choice.

In recent years, the use of more flexible model formats, such as mixed multinomial logit (MMNL) model and cross-nested logit (CNL) model have increased. Through the relaxation of the IIA property, the MMNL model enables the model to be specified in such a way that the error components in different choice situations from a given individual are correlated (McFadden and Train 2000). With the use of MMNL modeling, Hess and Polak (2005a,b) modeled the choice of airport by air passengers departing from San Francisco, with attributes of ground access modes included in the models as explanatory variables. Their model results indicated that there are significant differences across air passengers in their sensitivity to various factors. In addition, the MMNL models lead to important gains in modeling accuracy and explanatory power in the analysis of air travel behavior.

The CNL models allow for joint representation of correlation along the choice dimensions, without requirements to use a multi-level nesting structure. It allocates a fraction of each alternative to a set of nests with equal logsum parameters across nests (Vovsha 1997). Hess and Polak (2006) applied CNL modeling to jointly analyze air passenger choices of airport, airline and access mode in the Greater London area. They found that CNL model offers significant improvements over simple MNL and NL models, and can serve as a valuable tool in airport choice modeling.

Besides travel time and travel cost, Nam et al. (2005) pointed out that when making mode choice decisions, travel time reliability also plays an important role. This is because lower travel time reliability results in late arrival and imposes a potentially high travel cost on the travelers. Nonetheless, due to non-recurrent traffic congestion, travelers cannot predict the exact travel time required. As a result, when making a travel mode choice, travelers allow extra time, generally referred to in the literature as a safety margin, in order to avoid late arrival. Owing to arrival time pressure to meet scheduled departure flight times and the high personal penalty for missing flights, allowing an adequate safety margin is particularly important to departing air passengers.

In Tam et al. (2008), the safety margin for airport ground access journey is defined as the difference between air passengers' preferred arrival time at the airport passenger terminal for check-in and their expected arrival time. Their results showed that the safety margin allowances have some impacts on airport ground access mode choice decisions, while business departing air passengers place a significantly higher value on safety margin for their ground access trips than non-business ones.

In addition to the effects of the safety margin allowance, the relative intensity of the relationship between satisfaction level and airport ground access mode choice behavior should also be considered. This is because, for service providers, understanding exactly what customers expect and their satisfaction level is the most important step in defining and delivering the quality service (Zeithaml et al. 1990). However, the service quality is difficult to measure quantitatively because of its intangibility, inseparability and heterogeneity. Therefore, McFadden (1986) proposed to include latent psychological variables, which measure the service performance and traveler satisfaction with the service, in choice models. The inclusion of the latent psychological variables can lead to a more behaviorally realistic representation of the choice behavior, and consequently, higher explanatory power. A number of researchers, including Kitamura et al. (1997), Morikawa et al. (2002), Sasaki et al. (1999), and Tam et al. (2010) considered the suggestion made by McFadden (1986) and introduced attitude factors in the choice model as explanatory variables. They found that interactive, two-way relationship exist between attitudes and behavior.

From the above literature review, two important observations can be made. Firstly, both travel time reliability and perceived service quality were found to be important factors affecting air passengers' airport ground access mode choices. Secondly, there is a need to strength the understanding of air passengers' airport ground access mode choice in Asian countries with a high market share of public transport for their air passengers do exit.

Thus, in this paper, the ground access mode choice behavior at HKIA is studied. As the statistics show that the total number of air passengers using HKIA has reached 49.7 million in the year 2010 (Hong Kong Civil Aviation Department 2011), and this figure is expected to be continuously increasing. Similar to Tam et al. (2010), an attitudinal variable regarding satisfaction level towards the mode choices is first constructed using Structural Equation Modeling (SEM), and then introduced into the MNL mode choice model as an explanatory variable. Other explanatory variables to be considered in this study include the safety margin allowances, travel time, travel cost, and some traveler characteristics such as residential status and age. It is believed that the integrated model enables the evaluation of the relationship between satisfaction level and airport ground access mode choice behavior, and a more reliable representation of air passenger ground access mode choice behavior can be identified. Hence, improvement and expansion on the existing HKIA transportation system can be grounded for coping with the increasing demand for airport related traffic. The findings from this study can be transferred to countries which have airport related ground transportation problems for further considerations.

2 Hong Kong International Airport

HKIA, located in the north of Lantau Island, is approximately 28 km from the Central Business District (CBD) that comprises Central and Tsim Sha Tsui (Figure 1). To ensure efficiency of travel to and from HKIA, the North Lantau Highway and the Airport Express (AE) Line were built. The North Lantau Highway provides a railway and roadway access to Lantau Island and the airport from urban Kowloon and Hong Kong. The Highway carries six traffic lanes, three in each direction, on the upper deck and two railway tracks on the enclosed lower deck, one in each direction. In addition, two traffic lanes are provided on the lower deck for emergency use, such as in severe weather conditions. The AE Line covers 35.3 km between HKIA and Central (i.e., Hong Kong Station), with two intermediate stops at Tsim Sha Tsui (i.e., Kowloon Station) and Tsing Yi (i.e., Tsing Yi Station) (Figure 1).

Five major ground access mode types to HKIA, the AE, buses, taxis, private cars, and courtesy vehicles comprising hotel vehicles and tour coaches have been identified. Both AE and buses are scheduled public transport modes and charge a predetermined fare. The AE, operated by the Mass Transit Railway (MTR) Corporation, is a fast-dedicated railway, linking the airport with the CBD. Over 20 bus routes operate, with two to three serving each of the major regions/districts in Hong Kong. Each of the bus routes has a specific travel path, and the buses stop at some pre-determined locations for passenger boarding and alighting. Taxis provide a convenient personalized point-to-point transport service, with fares typically calculated according to trip length by a

Figure 1 Location of Hong Kong International Airport

taximeter and according to rates established by the government. Private car users, in addition to fuel cost, have to pay toll fees for the Lantau Link and all other tunnels used. To attract private car users, the Airport Authority Hong Kong (AAHK) offered 30 minutes free parking at HKIA, with each additional hour charged at US$2.5. Courtesy vehicles are available to hotel guests and the public, and can be classified into two types, scheduled service and private limousine service. The scheduled courtesy vehicles run in 30 minutes intervals, while private limousine service is available upon the requests of passengers. Table 1 summarizes the characteristics of different ground access modes for HKIA. For easier comparison, the figures presented are based on traveling between Central and HKIA.

Although HKIA is a critical hub for international passengers and cargo, only a few studies on the ground access mode choices to HKIA exist. Thus, to cater for the growth of airport ground access traffic and facilitate actions for further development of the ground transportation system at HKIA, this study began from the fundamental level of interview surveys.

3 Data Collection

A two-wave modal split survey was carried out aiming to collect necessary data for determining the HKIA ground access modal split pattern and factors affecting such pattern. The first wave modal split survey was carried out between 30 June 2004 and 2 July 2004, while the second wave survey commenced on 1 May 2005 and ended on 3 May 2005. These two periods were selected because they are the peak air passenger traffic periods. The two-wave modal split survey allows comparisons between different seasons, high summer and spring.

The surveys targeted departing air passengers whose ground access trip began from the Hong Kong territory. Such passengers face greater arrival time pressures, owing to the necessity to meet scheduled flight departure times and also the travel time uncertainty for accessing the airport. These air passengers have greater need for reliable transportation to the airport. It was also felt that, more detailed information could be obtained from departing air passengers, whose ground access trip was already complete.

Table 1 Characteristics of Different Ground Access Modes
(for Traveling between Central and HKIA)

Mode	Travel cost (US$ [a])	Travel time [b] (minutes)	Headway (minutes)	Hours of operation
Airport Express	12.82	24	12	05:50 to 01:15
Bus	2.69 – 5.13	75 – 95	15 – 20 [c]	05:20 to 00:30
Taxi	35.90	30	---	---
Private car	19.23 – 21.79 [d]	30	---	---
Courtesy vehicle (scheduled service)	17.95	40	30	06:00 – 24:00

[a] US$1.00 = HK$7.80.
[b] Travel time required is estimated by the bus operator, the MTR Corporation and the Hong Kong Transport Department.
[c] Headway for a particular bus line, where headway = 60 / frequency per hour.
[d] This includes the toll fee for Lantau Link (US$3.85), the toll fees for cross harbour tunnels (ranging from US$2.56 to US$6.41) and the estimated fuel cost (US$12.82). Parking cost is excluded.

As suggested by Metropolitan Transportation Commission (2003), the length of the air journey is expected to correlate with the number of pieces of baggage carried by a traveler and hence with mode choice decisions. Therefore, stratified sampling was used in the surveys to ensure both long-haul and short-haul travelers were sampled. The flights were stratified and selected proportional to the length of the air journey to the first destination. The list of scheduled flights was downloaded from the HKIA website. The flights were classified into three major groups, (1) long-haul flights (air journey time of more than 6 hours), (2) short-haul flights departing to Mainland China, and (3) short-haul flights departing to other countries, such as Taiwan, Singapore and Japan. The departure time of the selected flights was sufficiently well-spaced in time (i.e., 1 to 1.5 hours apart), so that, for each selected flight, a reasonable number of departing air passengers could be interviewed.

Departing air passengers waiting to board the aircraft at the boarding gates were invited for interview. Seated air passengers were selected to ensure passenger comfort during the 10 minutes taken to complete the questionnaires. A systematic approach was used to select the respondents. The first person (from left to right) sitting in each row of seats next to their respective boarding gates was interviewed. Since air passengers should arrive at the boarding gates at least 30 minutes before the scheduled flight departure times, there was sufficient time to complete the questionnaire.

From a total 891 eligible respondents, in the first wave modal split survey, there was a 56 percent response rate. From a total of 963 eligible respondents interviewed in the second wave modal split survey, there was a 58 percent response rate. A total of 994 responses (475 from the first wave survey and 519 from the second wave survey) were useful for analyzing departing air passenger mode choice behavior for accessing HKIA.

3.1 Questionnaire Design

The questionnaires used in the two-wave surveys are slightly different. The questionnaire used in the first wave modal split survey includes three main parts. In the first part, information about the ground access trip to HKIA, including trip origin, travel time and travel cost of the chosen mode and alternatives available to the respondent, party size and number of pieces of baggage carried by the travel party, was requested. Respondents were asked to rate their satisfaction level on five selected service attributes of the ground access modes that they have ever used for accessing HKIA. The satisfaction level is rated using a 5-point Likert scale. The five service attributes included waiting time, in-vehicle travel time, travel time reliability, travel cost and walking distance to and from public transport stations and/or car parks. These five service attributes are critical factors affecting air passenger satisfaction level toward the mode choices.

The second part was SP scenarios. The aim of the SP questions was to determine how travel time reliability affects departing air passenger airport ground access mode choices. Four attributes, including mode choice, travel cost, travel time, and travel time reliability, were included in the SP scenarios. Mode choice has five levels, while each of the other three attributes has three levels, with one level better than, one level same as, and one level worse than the current situation for accessing HKIA. In the SP scenarios, travel time reliability is represented as the fraction of trips with unexpected delays of 15 minutes or more. It has been shown that survey respondents understood this representation of travel time reliability more easily (Brownstone and Small 2005; Small et al. 2005). Using the technique of orthogonal design, two sets of 25 profiles are generated using SPSS. A random number is assigned to each profile, and these random numbers are used to pair the profiles for comparison. However, it was found that some of the pairs consist of a mode choice better perform in all aspects. In addition, some of the choice pairs are rarely faced by the respondents in the reality. As a result, these pairs are dropped, so as to make the comparison as realistic as possible. A total of 12 choice pairs remained and included in the final questionnaire. During the interview, respondents were asked to view two pairs of profiles, and choose one of the two alternatives each time according to his/her preference. Table 2 illustrates one of the SP scenarios presented in the survey. In the third part of the questionnaire, demographic information, such as trip purpose, gender, age and residential status of the air passengers, was requested.

Based on the responses obtained from the first wave modal split survey, travel time reliability was found to be a critical factor affecting air passenger mode choices. Therefore, in the second wave modal split survey, questions relating to the safety margin allowance were added so as to examine departing air passenger perceived travel time variability of various ground access modes.

To determine the magnitude of safety margin allowed for airport ground access journeys, in the second wave modal split survey, the respondents were first asked to state the expected travel time required for using different modes, the earliest and latest time for having check-in at the airport terminal, then their preferred arrival time at the airport terminal such that they would feel comfortable and safe. The difference between air passengers' preferred arrival time at the airport passenger terminal for check-in and their expected arrival time is the safety margin allowed for the airport ground access journey. Figure 2 illustrates the time elements asked in the second wave modal split survey. The safety margin obtained from these questions were reasonable, as departing air passengers must have a preferred arrival time at the airport before the check-in counters cease acceptance of passengers.

Other questions asked in the second wave modal split survey were the same as those asked in the first wave. However, in order to keep the questionnaire short and increase the response rate, questions relating to passenger satisfaction on ground access services and the SP questions were discarded in the second wave modal split survey.

Table 2 Example of Stated Preference Scenario Included in the First Wave Modal Split Survey

	Alternative A	**Alternative B**
Mode	Airport Express	Bus
Total travel cost (US$)	12.80	3.20
Total travel time required (minutes)	45	80
Frequency of being late by at least 15minutes	0 of 10 trips	4 of 10 trips

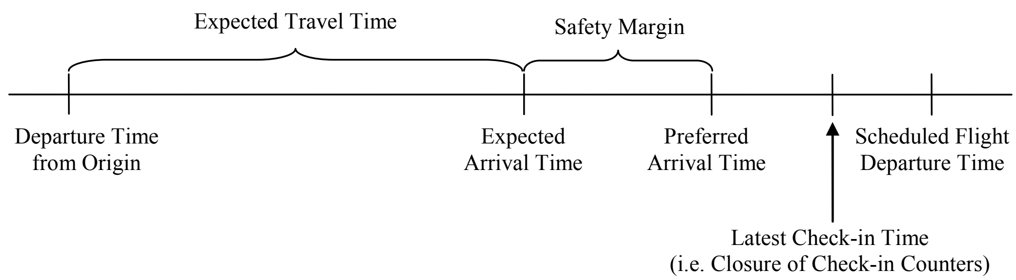

Figure 2 Graphical Representation of Time Elements Requested in the Second Wave Modal Split Survey

3.2 Survey Findings

It was found in the two-wave modal split survey that of the total 994 respondents, a majority (77 percent) used a single mode to access HKIA, and the remaining 23 percent used a combination of modes. In order to have a reasonable sample size for each mode type, in this study, the access mode refers to the final mode used by a respondent, as this mode is directly related to the design and improvement of the existing HKIA ground transportation system and the departure curb.

Public transport (including AE and buses) dominates the HKIA ground access market. Buses have a large proportion, 44 percent, while AE has 25 percent. The questionnaire responses revealed "low travel cost" to be the primary reason attracting respondents to using buses, while "high travel time reliability" was the major reason for those using AE. As HKIA is far from the urban area (i.e., 28 km from the CBD), access by taxis incurs a much higher travel cost. This consequently leads to a smaller market share by taxi, with only 14 percent of the airport ground access market. The use of private cars as the ground access mode to HKIA is limited, only accounts for seven percent of the airport ground access market, possibly owing to the low car ownership rate, five percent, in Hong Kong (Hong Kong Transport Department 2005).

Based on the results of the second wave modal split survey, it was found that business and long-haul departing air passengers accessing HKIA allowed a larger safety margin than the air passengers with other agendas. Those transported by buses also tend to allow a large safety margin as the travel time variation of buses is comparatively larger than the other airport ground access modes. More detailed survey results regarding the modal split pattern at HKIA and the safety margin allowed by departing air passengers can be found in Tam et al. (2008).

In the first wave modal split survey, the respondents were asked to rate their satisfaction level on five selected service attributes included waiting time, in-vehicle travel time, travel time reliability, travel cost and walking distance to and from public transport stations and/or car parks, using a five-point Likert scale. Over 90 percent of the respondents reported that they had not encountered any traffic congestion on their journey to HKIA, hence a relatively high satisfaction on travel time reliability is obtained. Waiting time is the least satisfactory attribute for bus users, while users of other modes are least satisfied with the travel cost. In general, departing air passengers perceived the best service from taxis, and it obtained relatively high satisfaction ratings in comparison with other airport ground access modes. The summary of passengers' satisfaction ratings on the five service attributes is presented in Tam et al. (2010).

Regarding the SP samples, a higher proportion of the respondents chose those alternatives with a low probability of unexpected delays. However, if the travel cost of a mode was much higher than that of an alternative, it is likely that the cheaper travel mode regardless of the higher probability of unexpected delays would be chosen. It was clear from the SP responses that travel time reliability has significant impact on departing air passenger mode choice decisions.

Using the revealed preference (RP) responses collected in the first wave survey and SEM approach, a "satisfaction" latent variable is constructed to capture departing air passenger preferences on the five airport ground access modes identified. A MNL mode choice model is then calibrated with the use of both RP and SP survey data collected from both waves of the modal split survey. Combining the RP and SP data allows elimination of the potential biases caused by (1) strong correlations among RP variables, such as travel time and travel cost, and (2) the habitual preference towards the RP choice when responding to SP questions. The "satisfaction" latent variable is included in the mode choice model as an explanatory variable.

4 Modeling Framework

4.1 Integration of Latent Variable Model and Discrete Choice Model

In this study, the framework applied to incorporate latent variable and the discrete choice model is similar to the one demonstrated by Morikawa et al. (2002). The framework consists of two components: (1) a discrete choice model and (2) a latent variable model. Both of these models consist of structural and measurement equations. RP and SP responses are described by the discrete choice model while the latent variable is described by a multiple indicators and multiple causes (MIMIC) model. The MIMIC model is a special case of the general structural equation models and has only one latent variable. The latent variable is directly affected by one or more independent observable variables, and it is indicated by one or more indicators. The MIMIC model is an alternative to multiple group models where there is more than one grouping variable and a larger sample size is required (Bollen 1989; Boomsma 1982; Muthen 1989). The MIMIC model is applied in this study as, based on the collected survey data, it was found that the sample size of using each access mode, particularly those of private cars and courtesy vehicles, is limited. Thus, to avoid non-convergence and improper estimations due to the bias of small sample size, the conceptual framework of the latent variable model is a MIMIC model.

In Figure 3, the ellipses represent unobservable variables and rectangles represent observable variables. Solid arrows represent the structural equations while dashed arrows represent the measurement equations. The latent variable model, which is the same as the one presented in Tam et al. (2010), describes the relationships between the latent variable and its indicators and causes. The discrete choice model explains departing air passenger mode choices. For the sake of simplicity, a MNL model integrated with a latent variable model is presented. In the equations below, superscripts "RP" and "SP" denote the corresponding data.

The structural equations are represented as:

$$U_n^{RP} = \beta_n^{RP} X + \alpha_n \eta + \varepsilon_n^{RP} \tag{1}$$

$$U_n^{SP} = \beta_n^{SP} X + \omega_n y_n^{RP} + \varepsilon_n^{SP} \tag{2}$$

$$\eta = \gamma X + \zeta \tag{3}$$

in which U_n is the utility of alternative n. X is a vector of observable explanatory variables, including the characteristics of the modes, of the trip and of the traveler. η is the latent variable regarding the satisfaction of departing air passengers on various airport ground access modes. y_n^{RP} is the mode choice indicator, it is equal to "1" if alternative n is chosen and "0" otherwise. β_n, α_n, ω_n and γ are vectors of unknown parameters. ε_n and ζ are the random disturbance terms. It is assumed that ε_n and ζ are independently logistic distributed. This yields the familiar logit formula for the choice probability conditional on parameters.

The measurement equations are represented as:

$$y_n^{RP} = \begin{cases} 1, \textbf{if } U_n^{RP} = \max_m \{U_m^{RP}\} \\ 0, \textbf{otherwise} \end{cases} \tag{4}$$

$$y_n^{SP} = \begin{cases} 1, \textbf{if } U_n^{SP} = \max_m \{U_m^{SP}\} \\ 0, \textbf{otherwise} \end{cases} \tag{5}$$

$$I = \lambda\eta + \delta \tag{6}$$

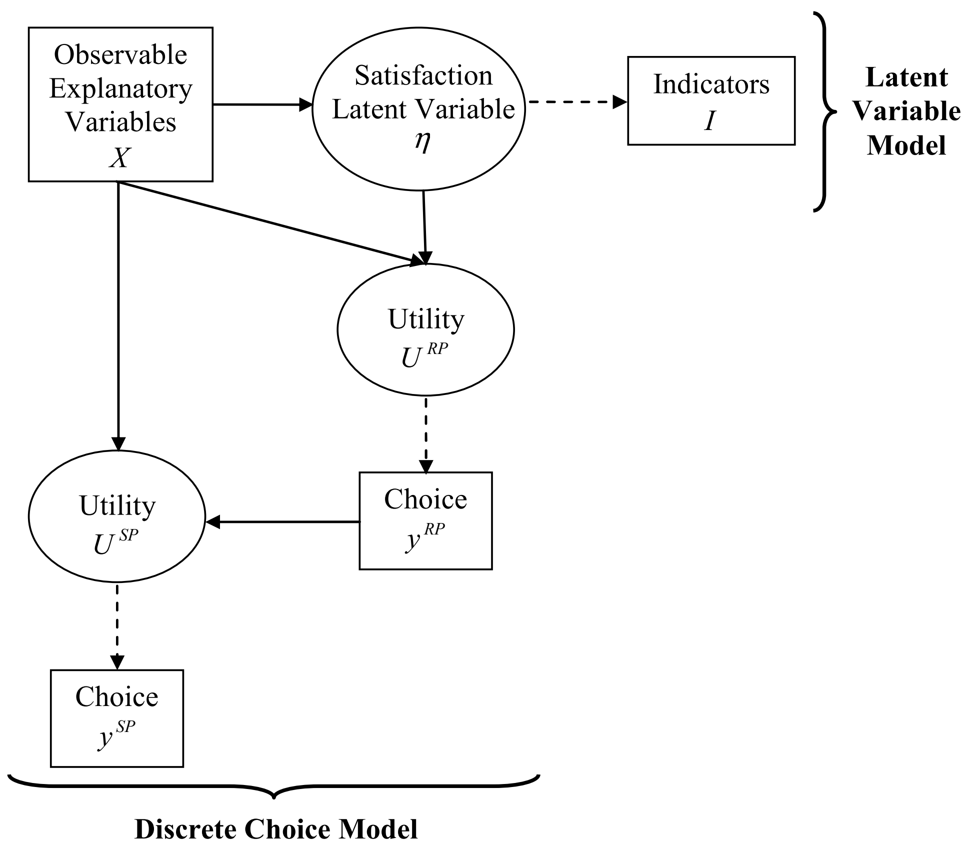

Figure 3 Integrated Discrete Choice and Latent Variable Model

where I is a vector of observable indicators of η. λ is a vector of unknown parameters for η, and δ is a vector of random disturbance terms. ζ and δ are assumed to be mutually un-correlated.

In this study, Equations (1), (3) and (4) form the RP choice model. The SP choice model composes Equations (2) and (5). It is noted that people usually display time inconsistency in the actual and stated contexts (Small et al. 2005), while travel time is a component determining the value of the "satisfaction" latent variable. Therefore, to reduce the potential error, the "satisfaction" latent variable is excluded in the SP choice models.

As suggested in Morikawa et al. (2002) and Small et al. (2005), the SP responses may be biased towards the travel mode which has been selected in the actual choice context. Therefore, an inertia dummy variable "y_n^{RP}", which indicated the actual choice, is included in Equation (2) to capture the correlation between the RP and SP responses. Equations (3) and (6) construct the latent variable model.

In combining the RP and SP data, the variances of ε_n^{RP} and ε_n^{SP} are usually allowed to be different so as to distinguish different sources for random preferences over the revealed and stated choices. This can be accomplished by normalizing the variance of ε_n^{RP}, which is represented as:

$$\mu \equiv \sigma^{RP} / \sigma^{SP} \tag{7}$$

where μ is the RP-SP scale parameter, and each σ is the standard deviation of the corresponding ε_n.

The RP questions asked in both waves of the modal split surveys were generally the same, except in the second wave survey, questions regarding safety margin allowances for the airport ground access journeys were asked. Hence, it is assumed that the variances of ε_n^{RP} between the two waves are the same, and no scale parameter is required. However, as departing air passengers are expected to react differently to travel time and travel cost in an actual and in a hypothetical situation, the parameters of the variables varying by modes are allowed to differ across the RP and SP data, whereas the other variables have the same effect across the two data sets (Mark and Swait 2004; Small et al. 2005). This approach provides a more precise estimation of departing air passenger airport ground access mode choice behavior.

In this study, a sequential estimation method is employed to calibrate the unknown parameters of the integrated model because it is less cumbersome to estimate the model sequentially than simultaneously (Johansson et al. 2005). LISREL (Joreskog and Sorbom 1993) was employed for the development of the MIMIC model with the use of first wave modal split survey data. Responses to the attitudinal questions of the first wave survey are listed as indicators of the "satisfaction" latent variable. The structural relationships between departing air passenger satisfaction and their observable characteristics are therefore determined. Based on the calibrated structural equations of the MIMIC models, departing air passenger satisfaction on various airport ground access modes is quantified. The "satisfaction" latent variable is then included in the discrete choice models as an explanatory variable. The calibrated structural equations of the MIMIC model are then used to estimate the value of "satisfaction" latent variable for the second wave survey respondents. The "satisfaction" latent variable is included in the MNL model, which calibrated with the use of NLOGIT3.0

(Greene 2002). The incorporation of the "satisfaction" latent variable can lead to a more robust representation of departing air passenger choice processes.

4.2 Exogenous Sample Weights

Although stratified sampling was employed in the surveys, it was found that there is difference between the profile of the respondents and that of the population, regarding their trip purposes and residential statuses. As shown in Table 3, in the two-wave modal split survey, Hong Kong residents, particularly those who traveled for business, were over-sampled. In contrast, visitors who traveled for non-business purpose were under-sampled. Thus, to obtain consistent estimates in the mode choice models, each individual observation is weighted by the fraction of population belonging to a segment over the corresponding fraction of the respondents (Garrow et al. 2005).

In this study, the departing air passengers are classified into four segments, (1) business Hong Kong residents, (2) non-business Hong Kong residents, (3) business visitors, and (4) non-business visitors. The population fractions of departing air passengers belonging to each of these four segments were obtained from the AAHK, while the corresponding fractions of the respondents were calculated from the collected survey data. The sampling weights are applied to the process of the model calibration so as to eliminate the estimation errors raised from the sampling bias.

5 Calibration Results

The latent variable model presented in Tam et al. (2010) consists of five indicators including waiting time, in-vehicle travel time, travel time reliability, travel cost and walking distance to and from public transport stations and/or car parks. In addition, four observable explanatory variables, including one characteristic of the modes (i.e., travel time) and three traveler characteristics (i.e., gender, age and education level), were identified as the causes of the "satisfaction" latent variable. As this paper emphasizes the results of the integrated model, the findings of the latent variable model are not discussed, but it can be found in Tam et al. (2010).

As mentioned in Section 4, travelers usually react differently to travel time and travel cost in an actual and in a hypothetical situation, and their values of time (VOTs) and values of transfer varied in accordance with different circumstances. Therefore, in the integrated model, the parameters of the variables varying by modes are allowed to differ across the RP and SP data, whereas the other variables have the same effects across the two data sets. This approach provides a more precise estimation of departing air passenger airport ground access mode choice behavior.

Table 3 Profile of the Population and the Sample

Segment	Population share [a]	Sample share
Business Hong Kong residents	0.045	0.107
Non-business Hong Kong residents	0.405	0.459
Business visitors	0.193	0.165
Non-business visitors	0.357	0.270

[a] Figures as at 2004 (annual data) from the Airport Authority Hong Kong.

In addition, to accomplish the different sources for random preferences over revealed and stated choices, an RP-SP scale parameter (μ) has to be included in the integrated model estimation. The RP-SP scale parameter of 0.431 maximized the model log-likelihood, hence it is selected and applied for estimating the model.

The results of the integrated model, which calibrated using the 994 responses obtained from the two-wave modal split survey, are given in Table 4. Most of the parameters are significantly different from zero at the 0.05 level of significance and have the expected sign.

It is reassuring that the estimated RP coefficients in the integrated model basically maintain the relative values obtained in Tam et al. (2008) (also shown in the last column of Table 4). The safety margin, which referred to as the additional time allowed by the departing air passengers in anticipation of travel time uncertainty for their ground access to HKIA, is negatively related to the mode utility. This is because departing air passengers tend to select a mode which they perceive to be more reliable, to minimize the chance of encountering unexpected delays. Based on the model results, the value of safety margin (VOSM) for departing air passengers is US$0.11 per minute.

In addition to safety margin allowance, departing air passengers trade-off travel costs with travel time and number of transfers required for accessing HKIA. The model results showed that business departing air passengers are substantially more averse to travel time insecurity than non-business ones. The former are willing to pay for a higher cost to reduce the travel time required for accessing the airport. The VOTs for business and non-business passengers are US$0.27 per minute and US$0.11 per minute respectively. Similar findings were revealed by Harvey (1986), Pels et al. (2003) and Tam et al. (2008). The VOTs for business and non-business departing air passengers obtained from Harvey (1986) were US$0.69 per minute and US$0.33 per minute respectively. Pels et al. (2003) found that the VOTs for business departing air passengers ranged from US$1.97 per minute to US$2.90 per minute and ranged for non-business departing air passengers from US$1.58 per minute to US$1.60 per minute. In Tam et al. (2008), the VOTs for business departing air passengers were US$0.25 per minute, and that for non-business departing air passengers were US$0.10 per minute. The higher VOTs obtained by Harvey (1986) and Pels et al. (2003) may be due to travelers being transported by private cars tending to have a higher VOT than those traveling by other modes.

Similar to the results obtained in Tam et al. (2008), both models revealed that departing air passengers have a lower safety margin value than for travel time. This is because departing air passengers, who allowed a large safety margin, arriving at HKIA earlier than expected, can only spend their unused safety margin within the airport passenger terminal.

It was noted that the SP VOTs for business and non-business departing air passengers are US$0.25 per minute and US$0.08 per minute respectively, which is smaller than the RP values. The differences arise because people tend to overstate the actual travel time they experienced in the revealed choice context. Hence, they are more responsive to a given actual time saving than to a hypothetical time saving of the same amount, and yield a smaller VOT in the SP than in the RP circumstances. By normalizing the variances between the RP and SP data, the value of travel time reliability (VOR), which equals US$1.66 per incident, is obtained from the integrated model.

Table 4 Parameter Estimates for Multinomial Logit Model

	In this study	In Tam et al. (2008)
	Coefficient (t-statistics)	Coefficient (t-statistics)
RP variable		
Alternative specific constant for		
AE	0.3703 (1.104)	-0.0670 (-0.369)
Bus	1.4115 (5.184)	0.5056 (2.451)
Taxi	0.4285 (2.111)	-0.5978 (-5.265)
Private car	0.8706 (3.346)	0.2231 (1.275)
Cost	-0.0913 (-10.394)	-0.1203 (-15.049)
Time	-0.0101 (-2.424)	-0.0118 (-5.111)
Time(Business)	-0.0147 (-2.653)	-0.0187 (-4.077)
Safety margin	-0.0099 (-4.779)	-0.0106 (-2.642)
Transfer	-0.3264 (-2.220)	-0.2726 (-2.727)
Satisfaction	1.4385 (2.798)	
SP variable		
Alternative specific constant for		
AE	-0.0952 (-0.249)	
Bus	-0.1065 (-0.534)	
Taxi	0.2864 (0.694)	
Private car	0.6314 (1.724)	
Cost	-0.0811 (-2.555)	
Time	-0.0067 (-0.713)	
Time(Business)	-0.0132 (-1.984)	
Unreliability of travel time	-0.1343 (-2.003)	
Transfer	-0.6741 (-1.539)	
Pooled variable		
Party size (specific to AE)	-0.0294 (-1.050)	-0.0088 (-1.039)
Baggage (specific to AE)	-0.3898 (-3.164)	-0.3209 (-3.199)
Party size (specific to bus)	-0.0678 (-2.644)	-0.1721 (-2.255)
Baggage (specific to bus)	-0.2741 (-2.352)	-0.1783 (-1.784)
Long-haul (specific to bus)	-0.5981 (-3.369)	-0.9545 (-5.917)
Age 25 (specific to bus)	0.1544 (0.888)	0.4905 (3.545)
HK (specific to AE and bus)	0.7603 (4.108)	0.4178 (2.955)
Age 65 (specific to taxi, private car and courtesy vehicle)	0.8452 (2.064)	1.4101 (3.101)
Other parameter		
Inertia dummy	0.6624 (6.993)	
RP-SP scale parameter (μ)	0.4310 (4.710) *	

* The t-statistics corresponding to the RP-SP scale parameter is computed with respect to a value of 1; a value of 1 indicates no scale difference in the RP and SP choice contexts.

The VOTs obtained from the SP-based MNL model are compared with those obtained in the Travel Characteristics Survey (TCS) conducted by the Hong Kong Transport

Department in 2002. In the TCS, SP questions were asked with the aim of investigating the VOT of the population regarding their daily travel. The overall VOT deduced from the TCS is US$0.07 per minute (Hong Kong Transport Department 2003), which is lower than those values obtained in this study. This result indicates that owing to the higher penalty for arriving late at HKIA, departing air passengers, particularly those traveling for business, are willing to pay a higher cost for accessing the airport than for their daily travel.

The "satisfaction" latent variable has a positive estimated parameter. This implies that, as expected, the mode utility increases with passenger satisfaction level. More importantly the parameter estimated for the "satisfaction" latent variable has a larger magnitude compared with other variables. This implies that the "satisfaction" latent variable dominates other variables, which lend support to the notion that satisfaction level is associated with departing air passenger airport ground access mode choice behavior. It was further noted that the inclusion of the "satisfaction" latent variable significantly improves the model calibration results, with the likelihood ratio test χ^2 = 7.56 given a chi-square statistic 3.84 with one degree of freedom at the 0.05 level of significance. This indicates that the inclusion of the "satisfaction" latent variable into the mode choice model provides a better estimation of the departing air passenger ground access mode choice behavior.

It is further revealed that, in the RP sub-model, the coefficient of the travel time variable becomes less significant, as compared with Tam et al. (2008), probably due to multicollinearity. This is caused by the reason that the variable of travel time is included in both the structural equations of the MIMIC model and the MNL mode choice model.

In the integrated model, the trip and traveler characteristics affecting alternative specific preferences are assumed to have the same effects across the RP and SP data. The results of the integrated model show that party size negatively affects the usage of AE and buses. This is because these two modes charged a fixed per-person cost. Thus, departing air passengers traveling in groups tend not to select these two modes but use taxis and private cars, for which the travel cost can be shared among the traveling party.

The number of pieces of baggage carried by a departing air passenger also has a negative impact on the utilization of AE and buses. This can be partly explained by the fact that these two modes offer less direct services, and departing air passengers carrying more and/or larger baggage require greater physical effort to walk to the public transport stations and are thus less likely to use these two modes. Comparatively, the number of pieces of baggage has a smaller impact on the usage of buses than that of AE. This is because departing air passengers sometimes give preference to the buses particularly when the bus stops are close to the departure point at their origins, thus they avoid transferring between modes as when using AE.

Departing air passengers having long-haul trips are less likely to access HKIA by buses due to the unreliability of travel time perceived by departing air passengers. However, those aged below 25 have a higher tendency to use buses owing to the comparatively low travel cost.

Hong Kong residents are believed to be more familiar with the local transport system, and thus have a higher tendency to be transported by AE and buses. The integrated model further revealed that elderly (i.e., aged above 65) preferred non-public modes (including taxis, private cars and courtesy vehicles) as these modes offer point-to-point and comfortable access services to HKIA.

The inertia dummy variable, which indicates the impact of the RP choice on the SP choice, is also estimated precisely. The positive coefficient of the inertia dummy variable indicated that, when responding to the SP scenarios, the respondents have a habitual preference towards their RP choices. The RP-SP scale parameter (μ) of value 0.431 indicates the error variance of the SP data to be much higher than that of the RP data.

The high likelihood ratio index (ρ^2=0.72) represents a good fit for the model. Around 80 percent of all the observations, in which 84 percent (836 out of 994) RP observations and 76 percent (731 out of 956) SP observations were predicted correctly by the integrated model.

As the integrated model provides reliable estimates for both the RP and SP choice contexts, as well as having a high prediction power, it is recommended to the AAHK and various transport operators that it can be used as a dialogistic tool for evaluating the impacts of changes of the service attributes on modal split pattern at HKIA. The RP sub-model allows prediction of modal split pattern under actual choice contexts, whereas the SP sub-model permits to investigate the impact of travel time reliability on departing air passenger mode choice decisions. Hence, the AAHK can improve the terminal frontage design and various transport operators can also enhance their services more effectively.

6 Policy Implications

In response to the airport-generated congestion problems, governments have initiated an increase in the use of public transport for accessing airports. For example, it was suggested that increasing bus frequencies, providing new bus routes and developing rail links to airports, can reduce car dependency for ground access trips to the United Kingdom airports (Humphreys and Ison 2003).

To propose strategies for coordinating HKIA ground access problems and further increasing the utilization of public transport (i.e., AE and buses), sensitivity tests are performed with the use of the calibrated model. Hence, suggesting the necessary operational restructurings.

6.1 Improvement in Bus Services

The survey results indicated that departing air passengers are least satisfied with the travel time reliability of buses, and hence have to allow a large safety margin for accessing HKIA. Thus, for bus operators, they should focus on measures to improve the travel time reliability, hence reduce the required safety margin.

Figure 4 shows the changes of bus market shares in response to changes in safety margin allowance and travel cost. It was found that departing air passengers are more sensitivity to safety margin allowance than travel cost for journeys made by buses. If the bus operators can improve travel time reliability of buses and subsequently reduce departing air passenger safety margin allowance by 10 percent, a bigger market share would be resulted. The bus operators can also increase the bus fares by at most 20 percent in order to maintain its market share.

One of the ways to improve bus travel time reliability is to make investment in information technology and provide passengers up-to-date information on departure times and arrival times of airport buses at major bus stops. Hence, departing air passengers can adjust their departure times and reduce the safety margin allowed for

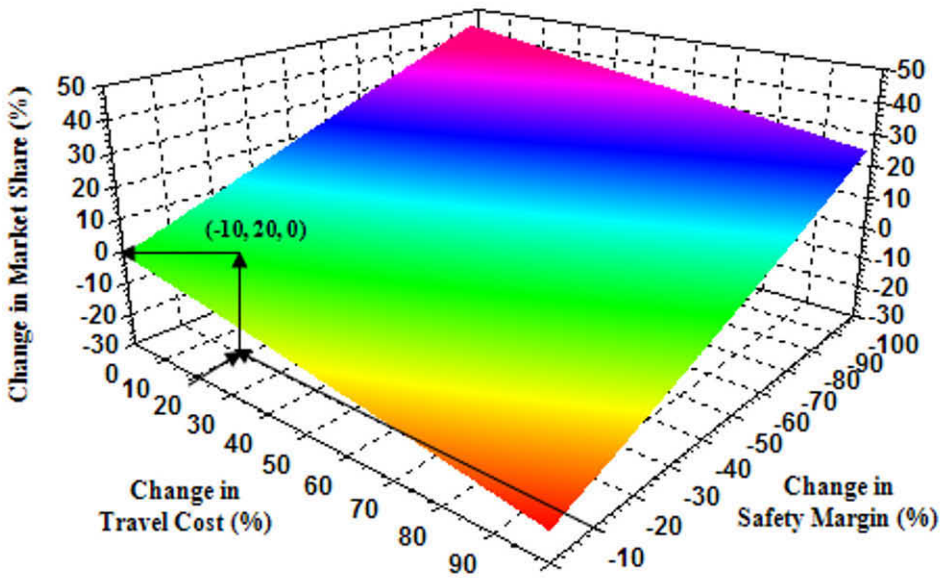

Figure 4 Changes in Bus Market Share in Response to Changes in Safety Margin and Travel Cost

the airport ground access journeys, accordingly. The results from the sensitivity test suggested that the bus operators may transfer the investment cost partially to passengers by increasing the fare charged.

6.2 Improvement in Airport Express Services

Rather than attempting to improve the already satisfactory travel time reliability, it could be advisable for the MTR Corporation to consider providing discounts to the AE users as survey respondents responded that the current charges of using AE are too high, with an average travel cost US$12.74 per person.

By assuming (1) the daily number of departing air passengers at HKIA is 30,000; (2) the ground access modal split of the population is the same as that revealed by the RP surveys; and (3) the distribution of party size of the population is the same as that of the survey samples, Figure 5 shows the revenue change in respect to different fare discount provided for departing air passengers traveling by AE in group of 2, 3, and 4 or more.

As shown in Figure 5, the MTR Corporation could maximize its revenue by offering a 20 percent fare discount to departing air passengers traveling in groups of two or three, and a 35 percent off the existing fare for those with four or more persons. This discount scheme would increase the MTR Corporation revenue by US$5,640 per day.

By offering fare discount to AE users, it is not only improving the market share of AE and its corresponding revenue. More than that, it helps to lessen the congestion problems on the road-way as well as at the departure curb. Hence, improving the departing air passengers' satisfaction level towards the airport ground access journey.

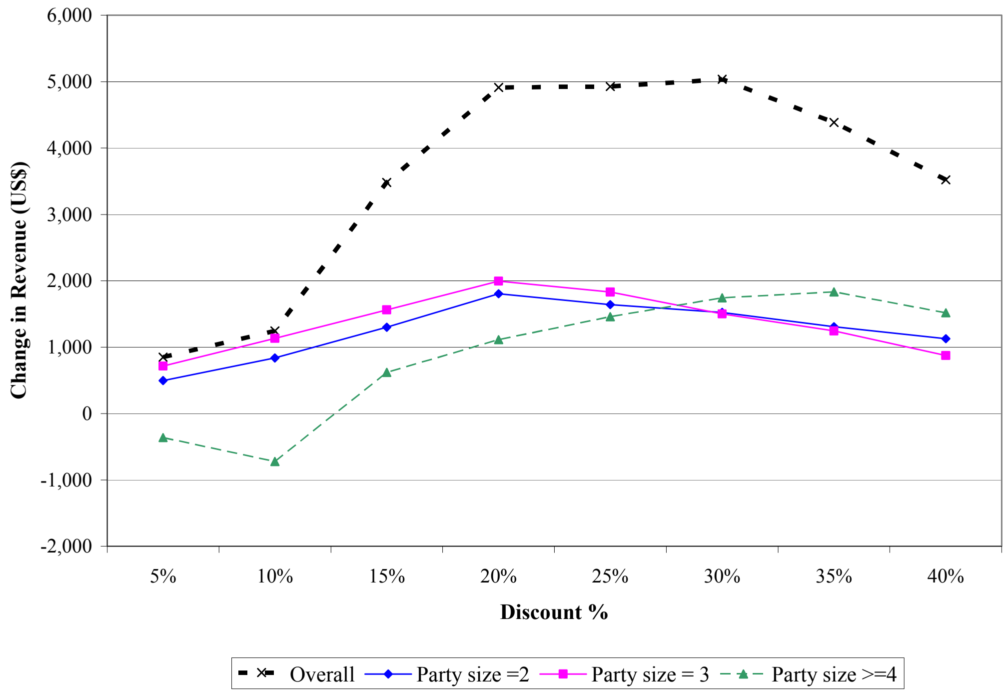

Figure 5 Revenue Change against Fare Discount for Grouped AE Users

7 Conclusions

In this paper, two contributions have been made to existing airport ground access mode choice models. The first is an assessment of travel time reliability on air passenger airport ground access mode choice decisions. The second contribution is the incorporation of air passenger perceived service quality in the calibration of the mode choice model. In addition, revealed and stated preference data were combined to calibrate the mode choice model so as to allow elimination of the potential biases caused by the strong correlations among RP variables. The habitual preference towards the RP choice when responding to stated preference questions can also be distinguished. The model calibrated in this paper outperforms the one developed in Tam et al. (2008), with an improvement on the ability of correctly predicting the modal choices of departing air passengers.

With the developed integrated model, sensitivity analyses have been carried out to assess the effects of various proposed strategies to increase the use of public transport (i.e., Airport Express (AE) and buses) for accessing Hong Kong International Airport (HKIA). It was found that if the travel time reliability of buses improved, a significant proportion of departing air passengers would switch to these buses for accessing HKIA. Offering discounts to grouped AE users increases the railway’s utilization. Attracting more trips to airports by public transport, particularly rail mode, is likely to reduce roadway congestion caused by an excess of non-public modes.

The calibrated model can be served as a diagnostic tool for evaluating the changes in service attributes on airport ground access modal split pattern in the short-term horizon, instead of a forecasting tool for long-term planning purpose owing to the difficulty to estimate the future values of safety margins. In further studies, the relationship between safety margins and observable factors including travel time, trip purpose, length of the air journey and air ticket type, has to be calibrated. Thus, safety margin can be included in the choice model as an explanatory variable, and the model then can be used for long-term planning purpose.

In the current empirical setting, only five service attributes regarding airport ground access modes are listed as indicators of the "satisfaction" latent variable. In further studies, more service attributes, such as ease of traveling with large baggage, safety and relaxation during the trip, can be used as the indicators of the latent variable. Hence, to obtain more detailed information on the service quality perceived by departing air passengers regarding the airport gourd access transportation service. This would also help to identify the areas that require service improvements, and add competitive advantages to the transport operators.

In total, 994 observations were obtained in the modal split surveys and used to calibrate the model in this paper. Further studies are suggested so that a larger sample size with adequate representation of less-used modes, particularly taxis and private cars, can be collected. This would enable to quantify separately the effects of different explanatory variables on taxis and private cars. In addition, by collecting more samples, separate models can be calibrated for departing air passengers with various trip purposes and/or air ticket types so as to allow a more fine-grained identification of distinct sub-markets.

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