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MODELING AIR PASSENGER TRAVEL BEHAVIOR ON AIRPORT GROUND ACCESS MODE CHOICES

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When considering mode choice criterion, departing air passengers allow a period of time, additional to the time allowance predicted for their ground access to airports. This additional time is commonly known as a "safety margin". The safety margin allowance increases the possibility of arriving at the airport no later than passengers' preferred arrival times. This study is the first to assess the magnitude of safety margin allowed for airport ground access trips. With the use of revealed preference survey data, the effects of safety margin allowances on ground access mode choices to Hong Kong International Airport (HKIA) are quantified by a multinomial logit-type mode choice model. The model results indicated that, when compared to non-business air passengers, business air passengers place a significantly higher value on both travel time and safety margin for their ground access to HKIA. The findings of this study provide valuable information to various transport operators for their design and improvement on airport related traffic.

KEYWORDS: Air passenger travel behavior, ground access mode choice, safety margin, Hong Kong International Airport

1. INTRODUCTION

Owing to the economic growth worldwide, the number of passengers traveling by air grew significantly in the past decade. Air passenger traffic is expected to keep rising at 4% per year until at least 2020 (Airports Council International, 2005). This has resulted in a globally concern regarding the air pollution caused by aircraft emission (Givoni, 2007). Another issue is the increase in airport ground access traffic and congestion, and is a subject of growing concern by airport authorities, in some regions.

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. The most recent MTC survey results showed that private cars had the largest market share and accounted for over 65% of the airport ground access markets in their region, whereas the use of public transport was found to be limited. Only 10% of departing air passengers accessed by this mode. The remaining 25% is shared among taxis and courtesy vehicles provided by hotels (Metropolitan Transportation Commission, 2003).

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. Travel time, travel cost and the number of pieces of baggage carried by an air passenger are significant explanatory variables in airport ground access mode choice models (Harvey, 1986). It was further noted that business air passengers are more sensitive to travel time while non-business air passengers are more sensitive to travel cost (Harvey, 1986; Pels et al.,

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2001, 2003). Other factors influencing airport ground access mode choices included trip purpose, party size and residential status (Clark and Lam, 1990; Shapiro et al., 1996).

However, when making mode choice decisions, travel time and travel cost are not the only considerations of the travelers, travel time reliability also plays an important role (Nam et al., 2005). 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 the literature relating to modeling airport ground access mode choice behavior, the effects of the safety margin allowance has yet to be considered.

In this study, the effects of the safety margin allowance on departing air passenger ground access mode choices to Hong Kong International Airport (HKIA) are investigated. It is believed that this is the first study devoted to evaluate the effects of a safety margin allowance on departing air passenger airport ground access mode choice behavior. The safety margin is newly defined as the difference between air passengers' preferred arrival time at the airport passenger terminal for check-in and their expected arrival time. This is slightly different from the conventional definition, in which a safety margin is defined as the additional time allowed by the traveler in anticipation of a journey time greater than the mean travel time. The definition difference arose to allow for the fact that departing air passengers visit the airport infrequently and the mean travel times by various modes are not well known to most of them.

In addition to the effects of the safety margin allowance, the impacts of travel time, travel cost, and various trip and air passenger's personal characteristics on ground access mode choices to HKIA are evaluated. Based on the analysis results, improvement and expansion on the existing HKIA transport system can be grounded, thus to cope with the increasing demand for airport related traffic. As the statistics show that the total number of air passengers using HKIA has increased by 8% and reached 43.86 million in the financial year 2006/2007 (Civil Aviation Department, 2007), and this figure is expected to be continuously increasing.

It was noted that a key feature of the HKIA ground access transport system is that public transport dominates the HKIA ground access market, and serves 70% of passenger trips to HKIA (Tam and Lam, 2005). Owing to the significant difference between the airport ground access modal split patterns between Hong Kong and the San Francisco Bay Area, the mode choice models calibrated by Harvey (1986) and Pels et al. (2001, 2003) are not applicable to investigate the modal split pattern at HKIA. Hence, there is a need for a data updated to reassess the use of various airport ground access modes to HKIA.

This paper is organized as follows. Background information on HKIA is given in Section 2. Data collection procedure is described in Section 3. The findings of the modal split surveys are presented in Section 4. The results of the multinomial logit-type (MNL) mode choice model as well as the sensitivity analysis are discussed in Section 5. Conclusions outlining the key findings are presented in Section 6.

2. HONG KONG INTERNATIONAL AIRPORT

The old Hong Kong airport, Kai Tak Airport, was a city airport and situated next to a densely populated residential area (Figure 1). This airport had a finite capacity owing to the constraints of the site. An increasing demand for air traffic was foreseen, thus there was a need to relocate the airport so as to provide sufficient capacity to support this anticipated growth. In 1989, the plan to relocate the airport to Lantau Island, as a part of an overall port and airport development strategy, was announced by the then Governor of Hong Kong.

FIGURE 1: Location of Hong Kong International Airport

Hong Kong International Airport (HKIA) started its operations in 1998, 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). HKIA is operated by the Hong Kong Airport Authority (HKAA) and is now one of the busiest airports in the world. It operates 24 hours a day with an annual design capacity of handling 45 million air passengers (including departing, arriving, and transfer/transit passengers) and three million tones of cargo. There are about 80 international airlines serving Hong Kong, which together operate about 5,500 scheduled passenger and all-cargo flights weekly between Hong Kong and some 150 cities worldwide.

The total number of passengers using HKIA has increased gradually over the years (Figure 2). The statistics of the Civil Aviation Department (1999-2007) show that between the financial years 1998/1999 and 2002/2003, the total number of air passengers grew by an average of 4.5% annually. However, due to the outbreak of the Severe Acute Respiratory Syndrome (SARS) across the region during March 2003 and June 2003, the annual air passenger flow at HKIA dramatically decreased to 28 million in the financial year 2003/2004. The annual number of air passengers rose back to 38 million in the financial year 2004/2005, and kept rising in the financial years 2005/2006 and 2006/2007.

In addition to transport passengers and cargo to worldwide destinations, HKIA has been developed as a commercial center with 260 outlets and 65 restaurants within the airport passenger terminal building and a hotel nearby (i.e. within 15 minutes walking time). The latest developments of HKIA include the opening of a golf course, the construction of a second airport hotel and a permanent cross-boundary ferry terminal. All are believed to impose an additional burden on the HKIA transport system.

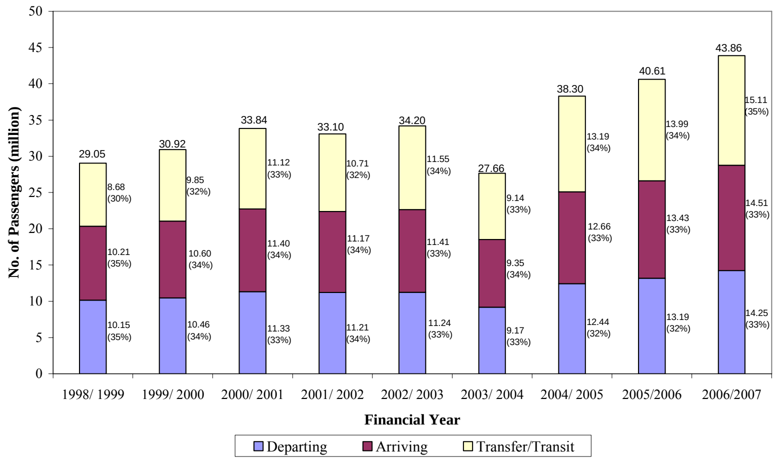

FIGURE 2: Air passenger statistics at Hong Kong International Airport

To ensure efficiency of travel to and from HKIA, the Lantau Link and the Airport Express (AE) Line were built. The Lantau Link, consists of the Tsing Ma Bridge, the Kap Shui Mun Bridge and the Man Wan Viaduct, providing a railway and roadway access to Lantau Island and the airport from urban Kowloon and Hong Kong. The Lantau Link 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 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 HKAA offered 30 minutes free parking at HKIA, with each additional hour charged at US$2.05. Courtesy vehicles provided for hotel customers and by travel agencies are available to transport passengers between HKIA and hotels directly. These courtesy vehicles are available to hotel guests and the public, and can be classified into two types, scheduled service and private limousine service. For the scheduled service, the courtesy vehicles run in 30 minutes intervals, between 6:00 to 24:00. The vehicles stop at a number of hotels for picking up additional passengers.

These scheduled service is either inclusive in the tour package or passengers can purchase the tickets through their travel agencies or at hotels. For private limousine service, reservations are required. It runs 24 hours a day 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.

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	2.69-5.77	75-95	15-20 [c]	05:20 to 24:00
Taxi	42.31	30	---	---
Private car	19.23-21.79 [d]	30	---	---
Courtesy vehicle (scheduled service)	17.95	40	30	06:00 to 24:00

[a] US$1.00 = HK$7.80.
[b] Travel time required is estimated by the bus operators, 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 harbor tunnels (ranging from US$2.56 to US$5.13) and the estimated fuel cost (US$12.82). Parking cost is excluded.

At HKIA, the Ground Transportation Center (GTC) is the focal point of all airport ground access and egress modes. The GTC comprises four levels of passenger transfer and interchange activities. The departures curb at the top level is a vehicular drop-off area and directly connects to the passenger terminal building. It has a double-curb arrangement, with high occupancy vehicles such as buses and tour coaches using the inner curb, and private cars and taxis using the outer curb. The second level is the AE departures platform, while the third level is the AE arrivals platform. This arrangement allows the airport users access to the rail platforms without the need to change levels. The ground level of the GTC is used by pick-up facilities for the various transport modes. It includes a bus terminus, tour coach stations, hotel courtesy vehicle pick-up areas, car parks and a taxi station.

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 transport system at HKIA, this study began from the fundamental level of interview surveys.

3. DATA COLLECTION

3.1 Survey logistics

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 (Wednesday) and 2 July 2004 (Friday), while the second wave survey commenced on 1 May 2005 (Sunday) and ended on 3 May 2005 (Tuesday). 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. Table 2 depicts the schedules of the two surveys.

TABLE 2: Summary of survey schedule and survey response

	First wave survey	Second wave survey
Date	30 Jun 2004 (Wed) to 2 Jul 2004 (Fri)	1 May 2005 (Sun) to 3 May 2005 (Tue)
Time period	08:00 – 22:00	08:00 – 22:00
No. of passengers being interviewed	1103	1369
No. of eligible respondents	891	963
No. of responses	498	561
No. of useful responses	475	519
Response rate	55.89%	58.26%

Note: The "response rate" is the number of responses divided by the number of eligible passengers.

The surveys targeted departing air passengers, include both Hong Kong residents and visitors to Hong Kong, 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 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.

The surveys were carried out at the boarding gates of HKIA. Importantly, it was noted that departing air passengers at the check-in area were less likely to respond to the interview requests as they were more eager to complete the check-in process and spend time with well-wishers.

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 gate 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. To prevent any disruption or inconvenience, air passengers arriving at the boarding gates, just before closing time, were not interviewed. However, these passengers accounted for only a small proportion of the target.

Table 2 shows the levels of response revealed by the two surveys. From a total of 891 eligible respondents, in the first wave modal split survey, there was a 56% response rate.

From a total of 963 eligible respondents interviewed in the second wave modal split survey, there was a 58% 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.

3.2. Questionnaire design

The questionnaire used in the first wave modal split survey includes two 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. In the second part, 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 journey, 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 3 illustrates the time elements asked in the modal split survey, while the questions asked in the survey regarding the safety margin allowances are shown in the Appendix. 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. Using the data collected from the two surveys, factors affecting departing air passenger ground access mode choices were evaluated.

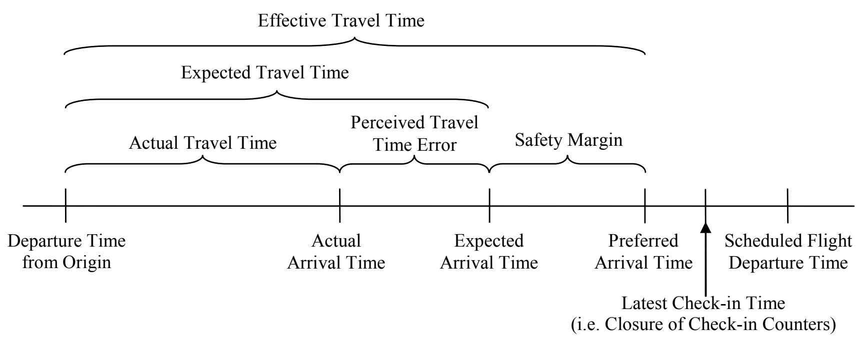

FIGURE 3: Graphical representation of time elements requested in the second wave modal split survey

4. SURVEY FINDINGS

4.1 Modal split pattern at Hong Kong International Airport

It was found in the two-wave modal split survey that of the total 994 respondents, a majority (77%) used a single mode to access HKIA, and the remaining 23% used a combination of modes (Table 3). Therefore, 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 transport system and the departure curb.

TABLE 3: Hong Kong International Airport ground access modal split

	First wave survey	Second wave survey	All
Sample size	475 (47.79%)	519 (52.21%)	994 (100%)
No. of transfers required			
0	376 (79.16%)	388 (74.76%)	764 (**76.86%**)
1	94 (19.78%)	125 (24.08%)	219 (22.03%)
2	5 (1.50%)	6 (1.16%)	11 (1.11%)
Mode choice			
Airport Express	117 (24.63%)	136 (26.20%)	253 (**25.45%**)
Bus	214 (45.05%)	221 (42.58%)	435 (**43.76%**)
Taxi	69 (14.53%)	69 (13.29%)	138 (**13.88%**)
Private car	35 (7.37%)	32 (6.17%)	67 (**6.74%**)
Courtesy vehicle	40 (**8.42%**)	61 (**11.75%**)	101 (10.16%)
Average travel time (minutes)	54.09	53.80	53.94
Average travel cost per person (US$) [a]	**8.88**	**9.69**	9.30

[a] The values are in 2005 dollars, US$1.00 = HK$7.80.

The survey results show that the seasonal effect is not significant and the modal splits, observed in the two waves, are similar. The largest difference occurs in the market share of courtesy vehicles provided for hotel customers and by travel agencies. Less respondents accessed HKIA by courtesy vehicles in the first wave survey, more accessed HKIA by courtesy vehicles in the second wave. The percentages were 8% and 12% respectively due possibly to fewer visitors being among the interviewees in the first wave survey than in the second. The seasonal differences between the other mode choices were fairly small.

More respondents in the second wave survey accessed HKIA by the more expensive travel modes (i.e. AE and courtesy vehicles) paying US$9.69 per person per trip. Those in the first wave paid US$8.88 per person per trip.

In general, public transport (including AE and buses) dominates the HKIA ground access market. Buses have a large proportion, 44%, while AE has 25%. 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% of the airport ground access market. The use of private cars as the ground access mode to HKIA is limited, only accounts for 7% of the airport ground access market, possibly owing to the low car ownership rate, 5%, in Hong Kong (Transport Department, 2005).

4.2 Effects of safety margin allowance on mode choice decision

As mentioned in previous section, in this study, the safety margin is newly defined as the difference between the preferred arrival time at the airport passenger terminal for check-in and the expected arrival time. The safety margin can also be represented as the difference between the effective travel time and expected travel time while the latter is equivalent to the summation of the actual travel time and perceived travel time error. Their relationships are given in equation (1), and Figure 3 presents them graphically.

[Effective travel time]
= [Preferred arrival time] - [Departure time from origin]
= [Expected travel time] + [Safety margin]
= [Actual travel time] + [Perceived travel time error] + [Safety margin] . (1)

It should be noted that, in the first wave modal split survey, no questions relating to the safety margin allowance were asked. Therefore, the safety margin analyses are based on the responses obtained from the second wave modal split survey only. The sample size in this respect is 519.

Based on the results of the second wave modal split survey, it was found that departing air passengers, who expected a long airport access travel time, left their point of origin earlier and allowed a larger safety margin, owing to the higher possibility of encountering traffic congestion. Table 4 shows that two-thirds of the 93 air passengers who had expected travel times of less than 30 minutes allowed a safety margin of less than 30 minutes. When the expected travel times increased to 30-45 minutes, around half of the respondents allowed a safety margin of less than 30 minutes, and one-third allowed a safety margin of 30-60 minutes. Half of those with expected travel times of between 45-60 minutes left a safety margin of 30-60 minutes. Of the total 81 respondents with expected travel times of more than 60 minutes, 42% left a safety margin of more than 60 minutes. In contrast, of those who expected to arrive HKIA within 30 minutes, only 5% included a large safety margin (i.e. a safety margin of more than 60 minutes). These 5% were visitors to Hong Kong who were taking long-haul flights. This possibly due to the reason that this group of passengers is less familiar with the transport system in Hong Kong, and, at the same time, incurred a high personal penalty for arriving the airport late. Hence, they tend to allow a larger safety margin compared with other types of departing air passengers.

TABLE 4: Expected travel time against safety margin intervals

Expected travel time, T (minutes)	Safety margin, SM (minutes)				No. of respondents
	SM ≤ 30	30 < SM ≤ 60	SM > 60	Total	
T ≤ 30	**68.82%**	27.96%	**5.38%**	100%	93
30 < T ≤ 45	**49.12%**	**36.26%**	14.62%	100%	171
45 < T ≤ 60	27.59%	**51.72%**	20.69%	100%	174
T > 60	23.46%	34.57%	**41.98%**	100%	81

As stated above, the magnitude of the safety margin is dependent on the length of the expected travel time for ground access to HKIA. For ease of comparison, the notation "P_{SE}" is used to denote the proportion of safety margin against the effective travel time. P_{SE} is represented as:

$$P_{SE} = \frac{\text{Safety margin (minutes)}}{\text{Effective travel time (minutes)}} . \quad (2)$$

Figure 4 depicts the relationship between P_{SE} and the ground access modes. AE is perceived to be the most reliable mode, and departing air passengers who accessed HKIA by this mode allow the smallest safety margin. In contrast, passengers considered buses the least reliable mode. One of the possible explanations is that travel by AE is less likely to encounter congestion or unexpected accidents on the road that may block the traffic. Therefore, those transported by AE could feel it unnecessary to allow a large safety margin than those selecting other airport ground access modes. Passenger safety margins for taxis, private cars and courtesy vehicles were similar. This can be explained by the fact that the private car users, taxi drivers and courtesy vehicle drivers each have a free choice regarding departure time and ground access route to HKIA. Departure time and route choice can be adjusted in response to roadway congestion.

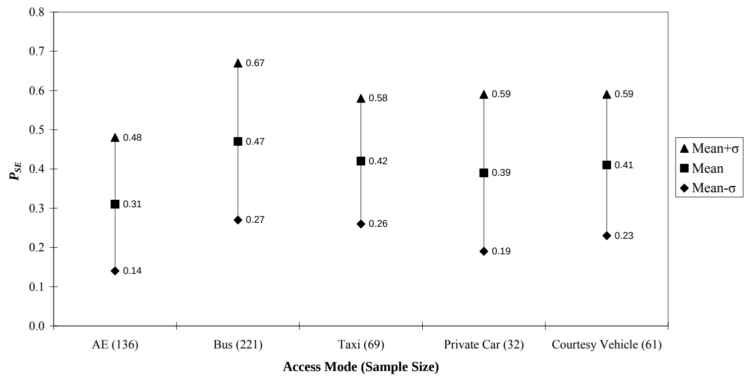

FIGURE 4: Distribution of the proportion of safety margin against the effective travel time, P_{SE}, against access mode

It was further found that the behavior of business and non-business departing air passengers was slightly different. Table 5 presents the average value of P_{SE} according to air passenger trip purpose. Business travelers allowed a larger safety margin than that allowed by non-business travelers. The differences for buses and taxis by trip purpose were significant at 0.10 and 0.05 level respectively. The difference between business and non-business air passengers could be due to business travelers having additional personal penalties (such as losing business, damage to company's image) if flights are missed. Thus they tend to allow a larger safety margin to offset the possibility of being late due to such as non-recurrent traffic congestion. However, as the travel time reliability of AE is notorious, there is no significant difference between business and non-business air passengers in the P_{SE} for this mode.

TABLE 5: Average value of the proportion of safety margin against the effective travel time, P_{SE}, by trip purpose

Mode	Business			Non-business		
	Mean	Standard deviation	No. of respondents	Mean	Standard deviation	No. of respondents
Airport Express	0.31	0.19	71	0.32	0.15	65
Bus	**0.51** [a]	0.21	58	**0.45** [b]	0.19	163
Taxi	**0.46** [c]	0.14	33	**0.38** [d]	0.16	36
Private car	0.37	0.20	11	0.40	0.20	21
Courtesy vehicle	0.45	0.20	27	0.38	0.17	34

Note: Statistically significant different at 0.10 level: ab; Statistically significant different at 0.05 level: cd

It is also expected that air ticket type may affect safety margin allowances. As, in general, the airlines give priority to air passengers having a first class or business class air ticket and allow them to change to another flights if their scheduled flights are missed. In contrast, if it is an economy class air ticket, which a relatively larger proportion of non-business air passengers tend to have, passengers are more difficult to change to another flights or having refund. Thus, the magnitude of safety margin allowed by departing air passengers traveling for different trip purposes and having different air ticket types are investigated.

It can be seen in Table 6 that the safety margins allowed by departing air passengers having economy class air tickets were slightly higher that those having business or first class air tickets. In addition, as the air tickets of air passengers traveling in tour groups are most likely to be non-refundable and non-changeable, this group of air passengers tends to allow a larger safety margin than any other groups of air passengers.

TABLE 6: Average value of the proportion of safety margin against the effective travel time, P_{SE}, for business and non-business travelers having different air ticket types

	Business traveler	Non-business – individual traveler	Non-business – tour group traveler	All traveler
Economy class air ticket	0.4161 [a]	0.3969 [b]	**0.4334** [c]	0.4098
Business or first class air ticket	0.4088 [d]	0.3836 [e]	---	0.4020
Overall	0.4150	0.4055		0.4092

Note: Statistically significant different at 0.10 level: ac, bc, de

However, due to the limited resources, the sample size of those having a business or first class air ticket was not large, and the differences between various groups of air passengers were not highly significant. This suggested that, for further studies, a larger sample with adequate representation of air passengers having different air ticket types should be collected. Hence, the relationship between safety margin allowances and air ticket types can be investigated.

Based on these survey results and the findings obtained from previous airport ground access studies, it is concluded that safety margin allowances, trip purpose, residential status, party size and number of pieces of baggage are all critical factors affecting the ground access mode choices to HKIA. Thus, in addition to travel time and travel cost, these factors are then considered in the discrete mode choice model that calibrated in the next section.

5. MODEL CALIBRATION

5.1 Modeling

In this study, multinomial logit-type (MNL) mode choice model is calibrated for modeling departing air passenger ground access mode choices to HKIA. It is assumed in the MNL model that each passenger aims to choose, from a selection available to them, a travel mode, which has a maximum utility. The utility of an alternative n, U_n, can be represented by:

$$U_n = \beta_n X + \varepsilon_n , \quad (3)$$

where X is a vector of explanatory variables. These variables include the attributes of the alternatives, and the characteristics of the trip and of the traveler. Table 7 defines the explanatory variables used in the calibrated model. β_n is a vector of unknown parameters and ε_n is a random component of utility. Assuming that ε_n is independently and identically Gumbel distributed across travelers and alternatives leading to the MNL model:

$$P_n = \frac{\exp(\beta_n X)}{\sum_{n'=1}^{N} \exp(\beta_{n'} X)}, \quad (4)$$

where P_n is the probability that alternative n is chosen, and N is the number of alternatives available to the traveler.

TABLE 7: Definitions of variables used in multinomial logit model

Variable	Description
Variable varying by mode	
Cost	Travel cost per person (US$)
Safety margin	Safety margin allowed by the respondent (minutes)
Time	Total travel time (minutes)
Transfer	Number of transfers required for accessing HKIA
Variable varying by trip or by traveler	
Business	Dummy variable, “1” if the trip purpose is business and “0” otherwise
Baggage	Number of pieces of baggage carried by the respondent
Party size	Party size of the respondent
Long-haul	Dummy variable, “1” if the length of the air journey is more than 6 hours and “0” otherwise
HK	Dummy variable, “1” if the respondent is Hong Kong resident and “0” otherwise
Age25	Dummy variable, “1” if the respondent was aged below 25 and “0” otherwise
Age65	Dummy variable, “1” if the respondent was aged above 65 and “0” otherwise
Alternative specific constant	
ASC-AE	Alternative-specific dummy for Airport Express
ASC-Bus	Alternative-specific dummy for bus
ASC-Taxi	Alternative-specific dummy for taxi
ASC-Private car	Alternative-specific dummy for private car

As revealed in Harvey (1986) and Pels et al. (2003), the values of time (VOTs) for business and non-business departing air passengers are different. Therefore, in this study, the variable “business” is made to interact with the “time” variable. The VOT for departing air passenger q is defined as:

$$\text{VOT}_q = \frac{\partial U_q / \partial T_q}{\partial U_q / \partial C_q}, \quad (5)$$

in which T is the measure of travel time and C is the measure of travel cost.

In previous section, attention was drawn to the findings that, comparatively, business departing air passengers tend to allow a larger safety margin as they bear higher penalties if flights are missed than non-business departing air passengers. This suggests that the interaction between “business” and “safety margin” should also be considered in the model. The value of safety margin (VOSM) for departing air passenger q can be defined as:

$$\text{VOSM}_q = \frac{\partial U_q / \partial \text{SM}_q}{\partial U_q / \partial C_q}, \quad (6)$$

where SM is the measure of safety margin.

When comparing the collected survey data with the annual HKIA statistics, regarding departing air passenger trip purposes and residential statuses, a difference between the profile of the respondents and that of the general population was found. As shown in

Table 8, in the surveys, Hong Kong residents, particularly those who traveled for business, were over-sampled. In contrast, visitors who traveled for business were under-sampled.

TABLE 8: Sampling weights

Segment (s)	Population share [a] (F_s / F)	Sample share (f_s / f)	Weight $(F_s / F)/(f_s / f)$
Business Hong Kong residents	0.045	0.0592	**0.7601**
Non-business Hong Kong residents	0.405	0.4475	0.9050
Business visitors	0.193	0.1125	**1.7156**
Non-business visitors	0.357	0.3808	0.9375

[a] Figures as at 2004 (annual data).

In order to obtain consistent estimates of the MNL model, each individual observation is weighted by the fraction of population belonging to segment s, (F_s / F), over the corresponding fraction of the respondents (f_s / f) (Garrow et al., 2005). The weight for respondents belong to segment s, W_s, can be expressed as:

$$W_s = \frac{F_s / F}{f_s / f}. \quad (7)$$

In this study, departing air passengers are divided into four segments, (1) business Hong Kong residents, (2) non-business Hong Kong residents, (3) business visitors, and (4) non-business visitors. The sampling weights, listed in Table 8, are applied to the process of the model calibration so as to eliminate the estimation errors raised from the sampling bias.

5.2 Model results

Around 80% (i.e. 785) of the survey observations obtained from the two-wave modal split survey was used for model calibration, and the remaining 20% (i.e. 209) was used for model validation. The MNL mode choice model is calibrated with the use of the software package NLOGIT3.0 (Greene, 2002). The calibration results are shown in Table 9. All the parameters have the expected signs and most are significantly different from zero at the 0.05 level of significance.

With regard to airport ground access, travel cost, safety margin, travel time and number of transfers required are shown to cause disutility for departing air passenger travels. This is understandable, as departing air passengers desire an airport ground access mode which offers fast, reliable and direct services at a minimum cost.

The model results showed that the safety margin allowed by departing air passengers traveling for business and non-business purposes are significantly different. This supports the findings raised in previous section that business departing air passengers demand for a more reliable ground access service for minimizing the chance of encountering unexpected delays, because their penalties for missing flights are higher than those of the non-business ones.

TABLE 9: Parameter estimates for multinomial logit model

Variable	Coefficient	t-value
Cost	**-0.1203**	-15.049
Safety margin	**-0.0106**	-2.642
Safety margin(Business)	**-0.0125**	**-1.995**
Time	**-0.0118**	-5.111
Time(Business)	**-0.0187**	**-4.077**
Transfer	-0.2726	-2.727
Baggage (specific to Airport Express)	-0.3209	-3.199
Party size (specific to Airport Express)	-0.0088	-1.039
Baggage (specific to bus)	-0.1783	-1.784
Party size (specific to bus)	-0.1721	-2.255
Long-haul (specific to bus)	-0.9545	-5.918
Age25 (specific to bus)	0.4905	3.545
HK (specific to Airport Express and bus)	0.4178	2.955
Age65 (specific to taxi, private car and courtesy vehicle)	1.4101	3.101
ASC-AE	-0.0670	-0.369
ASC-Bus	0.5056	2.451
ASC-Taxi	-0.5978	-5.265
ASC-Private car	0.2231	1.275
Summary statistics		
Log-likelihood at zero	-4452.1634	
Log-likelihood at convergence	-1724.6640	
Likelihood ratio index	0.6126	
Number of observations	785	

Based on the model results as well as the survey data, the VOSMs for business and non-business departing air passengers are determined and compared (Table 10). It was found that business departing air passengers have a higher VOSM than those traveling for non-business purposes. The VOSMs for business and non-business travelers obtained from the model are US$0.19 per minute and US$0.09 per minute respectively, while values obtained from survey are US$0.19 per minute and US$0.11 per minute respectively. The different VOSM between business and non-business travelers may be partly due to the fact that those traveled for business has a higher pressure as they are representing their organizations and going to join important meetings in overseas. Thus they have to arrive the destination on time and minimize the possible lost of the organization. Another possible reason is that business departing air passengers set their preferred arrival time closer to the scheduled flight departure time, increasing their need for travel time reliability.

TABLE 10: Values of safety margin for business and non-business departing air passengers having different air ticket types

Unit: US$ per minute	Business traveler	Non-business – individual traveler	Non-business – tour group traveler
Economy class air ticket	0.20	0.11	**0.13**
Business or first class air ticket	0.18	0.08	---
Overall (survey)	**0.19**	**0.11**	
Overall (model)	**0.19**	**0.09**	

Table 10 also shows that those traveling in tour groups have a slightly higher VOSM than other non-business travelers. It may be partly due to the reason that the air tickets of tour group travelers are most likely to be non-refundable and non-changeable. As a result, this group of air passengers has a higher penalty if their flights are missed, and they are willing to pay for a higher cost to minimize their travel time uncertainty for accessing HKIA.

Similarly, in comparison with those having a first class or business class air ticket, departing air passengers having an economy class air ticket are less easy to change to another flight if their scheduled flights are missed. Hence, they may be willing to pay a little more for using a relative reliable access mode so as to minimize the risk of delay.

On the other hand, it was found that the VOTs for business and non-business departing air passengers are significantly different. The values are US$0.25 per minute and US$0.10 per minute respectively. The VOTs obtained from this study are compared with those obtained in the Travel Characteristics Survey (TCS) conducted by the Hong Kong Transport Department in 2002. Stated preference questions were included in the TCS to investigate the VOT of the population regarding their daily travel. The overall VOT deduced from the TCS is US$0.07 per minute (Transport Department, 2003), which is lower than those values obtained in this study. This results indicate 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 VOTs obtained from this study and Transport Department (2003) are summarized in Table 11.

TABLE 11: Value of time for departing air passengers and commuters in Hong Kong

	Traveler type	VOT (US$ per minute) [a]
This study	Departing air passengers	0.10 – 0.25
Transport Department (2003)	Commuters	0.06 – 0.10

[a] The values are in 2005 dollars, US$1.00 = HK$7.80.

The calibration results further indicated that departing air passengers are sensitive to the number of transfers required for accessing HKIA. This is because transferring between different modes requires considerable physical effort, especially for those carrying large baggage. Therefore, departing air passengers crave point-to-point services and would be willing to pay US$2.27 to avert any required transfer.

Due to infrequent flight services to destinations with air journey time of more than 6 hours, departing air passengers have a longer waiting time for another flight if the scheduled flights are missed. As a result, departing air passengers taking such flights are less likely to access the airport by buses. This is because, as discussed in previous section, buses are perceived to be less reliable owing to their uncertain travel times and inflexibility of switching to other routes particularly in congested conditions.

Increase in party size also has a strong negative effect on the utility of AE and buses. This can be explained by the fact that departing air passengers traveling in groups can share the cost of a taxi or private car trip, while travel by AE and buses have to pay a fixed per-person cost. Similar to Harvey (1986), it was found that an increased number of pieces of baggage carried by a departing air passenger reduces the attractiveness of using public transport. The model results suggest that, for each piece of baggage, departing air passengers would be willing to pay US$2.67 and US$1.48 for a secure handling and storing service during an AE trip and a bus trip respectively. A higher value is obtained for AE because traveling by AE usually requires transfers from the Mass Transit Railway (MTR) or the AE shuttle buses, causing greater inconvenience than taking the buses for access to HKIA.

The calibration results further revealed that residential status affects departing air passenger mode choice decisions. Hong Kong residents are more familiar with the local public transport system, thus favoring the utilization of public transport. Departing air passengers aged below 25 are mainly students with low incomes, thus they are more likely to travel by buses which charge a lower cost. In contrast, departing air passengers aged above 65 demonstrate a higher use of non-public mode, such as taxis, private cars and courtesy vehicles. This may be due to the fact that these non-public modes offer direct and comfortable access to the airport, minimizing the physical effort required for walking to the public transport stations particularly with large baggage. Hensher (2007) also pointed out that multimodal planning usually heavily considered the needs of individuals in the younger age groups, while the needs of elderly are of minor concern.

The high likelihood ratio index of the model suggests that the model fits well. Around 82% of the observations were correctly predicted by the model. The validation results also showed that the calibrated model correctly predicted 86% of the observations. These statistics reinforce the predictive power of the model regarding future demand for various ground access modes to HKIA.

5.3 Sensitivity analysis

In order to further increase the efficiency for accessing HKIA, it is suggested that departing air passengers use buses. However, the survey results indicated that passengers are least satisfied with the travel time reliability of buses, and allow a large safety margin for accessing the airport. Thus, to increase the utilization of buses, the bus operators should focus on measures to improve the travel time reliability, hence reduce the required safety margin.

Figure 5 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 sensitive to safety margin allowance than travel cost for journeys made by buses. If bus operators can improve travel time reliability of buses and subsequently reduce departing air passenger safety margin allowance by 50%, it can increase its market share by 25%.

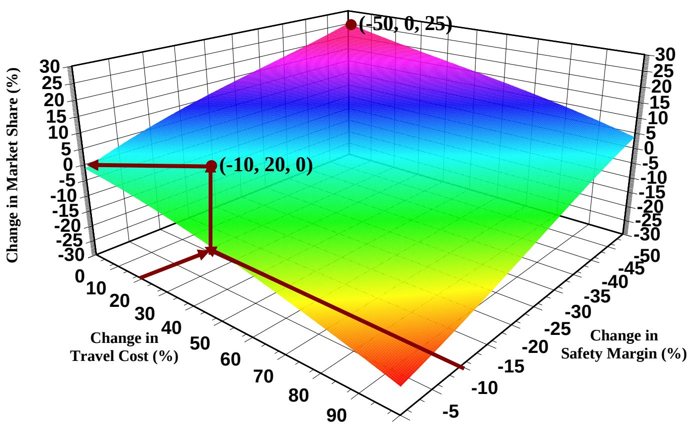

FIGURE 5: Changes in bus market share in response to changes in safety margin and travel cost

One of the ways to improve buses travel time reliability is to introduce bus-only lanes. The aim of a bus-only lane is to give priority to buses and save journey time in places where roads are congested with other road traffic. Thus, the introduction of bus-only lanes would reduce the bus delays due to conflict with other road traffic and minimize possibility of late arrival by buses when accessing HKIA.

Bus operators can also make investment in information technology and provide passengers up-to-date information on departure times and arrival times of buses at major bus stops. Hence, departing air passengers can adjust their departure times and reduce the safety margin allowed for the airport ground access journeys, accordingly. From Figure 5, it was found that the bus operators may transfer the investment cost partially to passengers by increasing the fare charged. For instance, if the safety margin allowance can be reduced by 10%, the bus operators can increase the bus fares by 20%. By doing so, the bus operators can still maintain its current share in the airport ground access market.

6. CONCLUSIONS

Owing to the higher penalty for missed flights, business and long-haul departing air passengers accessing Hong Kong International Airport (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.

Based on the multinomial logit (MNL) model calibrated for evaluating departing air passenger behavior regarding their ground access mode choices to HKIA, the value of safety margin (VOSM) and value of time (VOT) are quantified. It was found that the VOSM and VOT for business departing air passengers (VOSM: US$0.19 per minute; VOT: US$0.25 per minute) are significantly higher than those for non-business ones (VOSM: US$0.09 per minute; VOT: US$0.10 per minute). This is due to the reason that departing air passengers travel for business bear a high penalty if flights are missed than those have non-business trips. Thus, business air passengers are willing to pay a higher cost for a fast and reliable airport ground access transportation service.

The sensitivity analysis further indicated that to increase their market share, bus operators should improve the travel time reliability of their services. This subsequently leads to a reduction in safety margin allowance for accessing HKIA by buses. One possible way to achieve this is the introduction of bus-only lanes, which save journey time in places where roads are congested with other road traffic. The provision of real-time bus information would also help to reduce departing air passenger anxiety as well as safety margin allowance.

In total, 994 revealed preference data were collected in the two-wave modal split survey and used to calibrate the model in this paper. However, 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.

The calibrated model is mainly used for understanding departing air passenger ground access mode choice behavior in order to improve the airport access mode services in the short-term horizon, say one year. It can be served as a diagnostic tool for evaluating the changes in service attributes on airport ground access modal split pattern, 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 MNL model as an explanatory variable and the model can be used for predicting the demand of various airport ground access modes in long-time horizon.

In this study, the time period between the preferred arrival time and latest check-in time, also referred to as the preferred earliness of arrival, has not been considered. However, some researchers pointed out that the safety margin may be correlated with the preferred earliness of arrival, which in turn is correlated with the trip purpose. Thus, in further studies, the preferred earliness of arrival can be taken into account in the development of the choice model.

In addition, as suggested by Wen et al. (2005), perceived service quality on the mode choices plays an important role in passenger mode choice decisions. Thus, in further studies, the effects of passenger satisfaction regarding the airport ground access services should be taken into account explicitly in the MNL model. Latent variables should be constructed to capture departing air passenger preferences on different airport ground access modes. It is believed that by incorporating passenger satisfaction into the MNL model, airport ground access mode choice behavior can be modeled more precisely.

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APPENDIX

The following questions were asked in the second wave modal split survey so as to determine the safety margin allowed by departing air passengers for their ground access journey to Hong Kong International Airport.

1. Please state all the alternative modes that you've considered for accessing to this airport today.

No.	(i) Mode(s)	(ii) Travel cost per person	(iii) Estimated total time	(iv) Departure time from origin
1		HK$	min.	a.m. / p.m.
2		HK$	min.	a.m. / p.m.
3		HK$	min.	a.m. / p.m.

2. Finally, which mode or combination of modes did you use to get to the airport today? No. ____________

3. Today, when did you step in the airport terminal building? ____:____ am / pm

4. What is the earliest time you think you can have check-in at this airport? How long before flight departure? ________ min.

5. You expected that the check-in counter at the airport would stop the acceptance of check-in at what time? How long before flight departure? ________ min.

6. You prefer to have check-in how much time before the closing of check-in counter at the airport, such that you would feel comfortable and safe? ________ min.