Airport Ground Accessibility: Review and Assessment

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Abstract

Air travel has become one of the major modes of transportation in the last few decades. The magnitude of the air passenger market is expected to increase even faster in the near future, with increased industrialization, globalization and economic growth. According to the International Civil Aviation Organization (ICAO), the number of passengers grew by some 4.5 per cent to 3.1 billion, while commercial flight departures were up 1.2 per cent to 32 million, globally from 2012 to 2013. Along with other developed countries, Australia is also significantly contributing in this huge air passenger growth. As stated by the Bureau of Infrastructure, Transport and Regional Economics (BITRE), in Australia the number of international and domestic passenger movements is projected to increase by 4.9 and 3.3 per cent a year from 107.5 and 27.6 million in 2010-11 to 207.1 and 72.1 million in 2030-31 respectively. This substantial amount of air passenger growth is producing tremendous pressure on ground access networks and airports. In order to accommodate this growing air passenger demand, most major airports have extensive Ground Transport Plans (GTPs). Subsequently, several studies had been done in the last decades to understand the behaviour of air passengers' access to and from the airport. A number of factors have been investigated to identify the impact on airport ground accessibility, using cars, taxicabs, and public transport. In addition, several models and techniques have been applied to date. The main focus of this study is to understand the parameters affecting the airport ground accessibility, as well as to identify the factors influencing access that have been overlooked in previous studies. The study also discusses different models that had been applied to forecast airport mode choice based on previous literature. Finally, the study unveils the potential difficulties that require further study.

Keywords- Accessibility, Airport, Ground Transport

1. Introduction

Tourism is one of the rapid growing industries globally. Along with tourism amenities, comfort, luxury and time are other key variables which make the aviation industry valuable among passengers both in developing and developed countries. Moreover, industrial development, technological advancement and economic growth are considerably working powerfully for the aviation industry in last few decades. Besides, the introduction of low-cost carriers (LCCs) is another noteworthy milestone that the aviation industry has faced in the last decades. Air travel has become cheaper and easier in this era of LCCs that one would not have been even imagined. Most of these LCCs focus on underused or regional airports as their main hubs. Francis et al. (2004) found, due to the LCCs, there has been an upsurge in the usage and significance of many subordinate, often underused airports. Eventually the usage of these secondary or regional airports escalates the convenience of people living in

regional areas towards air travel. In fact, the catchment area for airports is becoming ubiquitous as previously which was only city based.

As a consequence, air passenger growth is increasing considerably in the last few decades. According to the International Civil Aviation Organization (ICAO) the number of passengers grew by some 4.5 per cent to 3.1 billion, while departures were up 1.2 per cent to 32 million globally from 2012 to 2013 (ICAO, 2014). The International Air Transport Association (IATA) released that by 2017 total passenger numbers are expected to rise to 3.91 billion- an increase of 930 million passengers over the 2.98 billion carried in 2012 (IATA, 2013). Like the other developed countries, Australia has also a remarkable contribution to this growth. As stated by the Bureau of Infrastructure, Transport and Regional Economics (BITRE), in Australia the number of international and domestic passenger movements is projected to increase by 4.9 and 3.3 per cent a year from 107.5 and 27.6 million in 2010-11 to 207.1 and 72.1 million in 2030-31, respectively (BITRE, 2012). As a result, more ground trips are created to and from airports for the purpose of air travel, which ultimately increases the burden on road networks. This condition has become exacerbated due to the intensive use of private cars for those journeys. At large airports 65% of ground access trips are carried by private cars, while at smaller local or secondary airports this number can be as high as 99%, which usually struggle to provide regular public transport facilities (Humphreys and Ison, 2005). This hefty reliance on private car has triggered congestion on local road networks and greater levels of pollution from vehicle emissions (Budd et al., 2011). Furthermore, kiss'-n'-fly journeys, with meeters and greeters, are substantially enhancing the stress on roadway system. The kiss'-n'-fly yields two more surplus trips, while the meeters and greeters yields four more trips (unless they accompany the air passenger) to and from the airport. These forms of journeys have more environmental penalties than others, because of the excess trips involved. In a recent study, Miyoshi and Mason (2013) found air passengers that drive and park cars at the airport yield a considerably lower volume of carbon dioxide per passenger km (75 g/pkm) than a drop-off/pick-up (kiss'-n'-fly) trip (229 g/pkm).

In order to reduce these environmental and economic impacts, public transport has been given priority in almost all the biggest airports in the world. However, only very few airports have been successful in attracting air passenger patronage to public transport systems. Oslo airport, located in the capital of Norway, has the highest share (64%) of air passengers using public transport. In addition, Hong Kong International Airport (63%), Narita International Airport in Japan (59%), Shanghai Pudong International Airport in China (51%), Zurich Airport in Switzerland (47%), Vienna International Airport in Austria (41%), and London Stansted Airport in the UK (40%) have high access market share for public transport. In USA the most successful airports are San Francisco International Airport (23%), John F. Kennedy International Airport (19%), and General Edward Lawrence Logan International Airport (18%) (Coogan, 2008). In Australia, Brisbane Airport counts 96% of trips by private vehicle including taxis and only 4% are by public transport, combining the transport choices of airline passengers and those who work at the airport (BAC, 2014). In Melbourne the share of public transport is 11.7% though the airport does not have any train service (APAM, 2013). The most successful airport in Australia is Sydney (Kingsford Smith) Airport which has 15% of public transport share (Train 11%, Bus 4%). Additionally, Minibus service (a dedicated airport service) has 10% of the total (SACL, 2009). In comparing with the most successful airports, these figures are quite low. In stark contrast to public transport promotion, parking revenue is one of the major earnings for the airport authorities. There is a common misperception that congested car parking spaces may discourage passengers to use private car and endorse modal change (TfL, 2014). However, in a constrained airport parking scenario, travellers favour kiss'-n'-fly rather than using public transport (Ricondo and Associates, 2010). As a result, the operators must balance between the private car trips with public transport for a better and more sustainable environment.

To achieve balance among access modes, to increase public transport mode share, and to plan for huge passenger growth, airports are fashioning extensive ground transport plans

(GTPs). Consequently, many studies have been done on ground travel behaviour of air passengers so as to promote public transport and reduce private car use. The key focus of these studies was to fathom the behaviour of air passengers in selecting certain modes to access the airport, with a desired outcome of reducing congestion and pollution for a better and sustainable future. Moreover, researchers have focused on diverse aspects of ground transport access, such as air passengers and airport employees, offsite terminal facilities, capacity and pricing of car parking, the influence of low cost carriers, the development of airport cities, and influences of travel time and travel time reliability on access behaviour. Various socioeconomic, demographic, and trip characteristics have been considered in those studies. However, there are several more areas that have not been scrupulously studied and in some cases that have been fully overlooked. Airport employee behaviour is one of those areas which has not been rigorously studied, and the behaviour of meeters and greeters at airports is largely ignored to date. Moreover, numerous techniques and models have been used, yet one standard technique or model has not been acknowledged by all practitioners globally. The main objective of this study is to identify the factors and models that have been incorporated in the previous literature along with their limitations. This study will also provide an indication of the state of the art and state of the practice. At the end this study will present the future scope of research to enhance the existing knowledge on airport ground accessibility.

2. Air Passengers Ground Accessibility

The aviation industry is swelling with increasing air passenger growth. Therefore, it is indispensable for airport operators to prepare sustainable and efficient strategies. These strategies should address not only aircraft handling or ground operations but also the passengers' contentment. The process from the passengers' origins to their boardings in the airplane has to be as smooth as possible. However, to do so operators must consider the social, economic and environmental aspects of the total journey. In fact, one must comprehend the full characteristics of air passengers to promote sustainable approaches. To explore the passengers' behaviour, researchers have identified various market segments, socioeconomic and demographic variables, methodologies, models and techniques. Table 1 shows a summary of research that has been conducted in previous years.

2.1 Market Segmentation

From the beginning of the airline industry, air travel was seen as a matter of prestige. Few people would have been able to afford the cost of air travel. However, after the airline deregulation act in 1978 in the United States, air travel has become a common mode of travel. Later on Australia, Canada, the United Kingdom, and the European Union followed the same path of economic deregulation and increased competition. In 2000, China, Thailand, India, and other Asian countries have also deregulated airlines (Neufville, 2006). Therefore, in the last few decades, people from various regions and backgrounds have had greater access and lower costs to travel both domestically and abroad by airplane. The purpose of air travel also dramatically changed: with increased globalization, people are now travelling not only for luxury but also for business, tourism, social visit, education, etc.

Passenger market segments have diverse priorities in order to access an airport. Harvey (1986) studied only two market segments, business travellers and non-business travellers. He also segregated resident and non-resident air travellers. The study revealed that business travellers are most sensitive towards airport travel time than other form of travel time. Non-business travellers are also time sensitive but not as much as business travellers. The value of time (VOTs) obtained from the study was US$41.4/h and US$19.8/h for business and non-business travellers, respectively. For both business and non-business travellers, service quality becomes an important parameter in the case of long haul travel.

Similar findings were revealed by Furuichi and Koppelman (1994), Pels et al. (2003), Hess and Polak (2005), Tam et al. (2008), Gupta et al. (2008), Tam et al. (2011), and Roh (2013).

Table 1: Studies on Air Passengers Mode Choice

Study	Market segmentation	Important variables	Models
Harvey (1986)	Resident business, resident non-business	Travel time, cost, distance to airport, trip purpose, income, household size	MNL
Furuichi and Koppelman (1994)	Business, pleasure	Access travel time, access cost, line-haul travel time, line-haul cost, relative frequency	NL and MNL
Psaraki and Abacoumkin (2002)	Resident and non-resident, business and non-business	Trip purpose, trip distribution, travel time, travel cost, car ownership	MNL
Chebli and Mahmassani (2003)		Attitudes and perceptions, return trip, social and environmental views, stated response to new services. hometown, age, gender, and education, household size, automobiles, number of licensed drivers	Ordered probit model
Gupta et al. (2008)	Business, non-business, resident, non-resident, international, domestic	Travel time, travel cost including transit fare, daily airport parking rate, Manhattan origin dummy, gender, age, income, party size	NL and MNL
Jou et al. (2011)		Time saving, transferring, comfort, user friendly, convenient luggage storing, rapidness, punctuality, sex, income, access cost, often used access mode	Mixed logit model
Tam et al. (2010)	Business, non-business	Waiting time, walking distance, travel time reliability, travel cost, trip purpose, gender, residential status, party size, baggage, education, transfer	Structural equation modelling and MNL
Mamdoohi et al. (2012)	Business, non-business	Sex, age, education, income, car ownership, trip purpose, travel time	Binary logit model
Choo et al. (2013)	Leisure, business, visiting relatives, other,	Travel distance, travel time, trip purpose, age income, occupation	Logistic regression
Roh (2013)	Standard distance, long distance, departing, non-departing	Accommodation, travel purpose, origin, travel time, travel cost, number of companions, sex, age, job, family size	MNL
Akar (2013)	Business, non-business	Sex, education, local user, employment, income, age, party size, trip purpose, duration between airport arrival time and departure time, flight time (AM or PM), parking, gasoline cost, luggage, safety, comfort, travel time, auto dependent, willing to reduce auto-use, weather conditions	Binary logit model
Hess et al.		Flight, including departure and arrival	MNL, NL,

(2013)	airport, airline, access mode	CNL
Bao et al. (2015)	Travel time, cost, trip purpose, number of pieces of luggage	NL, MNL, MXL

Tam et al. (2011) found VOTs for business and non-business passengers are US$16.2/h and US$6.6/h, respectively. Gupta et al. (2008) obtained VOTs of US$63/h and US$42/h for business and non-business travellers. However, Harvey (1986) did not analyse non-resident travellers. As Akar (2013) found, local users/residents have disparate priorities when compared with non-residents; for example, residents do not want to choose alternative modes to access the airport. The reason may due to the familiarity of the area where the airport is located and awareness of all the modal options. In addition, with business and resident status, Gupta et al. (2008) also considered segmentation among domestic and international passengers. This segmentation may be the reason for their high VOTs compared with those in other studies. As per the authors' knowledge, international passengers are more sensitive to their travel time due to the high ticket price, longer distances and less frequent journeys. Moreover, business travellers are highly influenced by peak travel time than non-business travellers (Mamdoohi et al., 2012). This obviously suggests the influence of business passengers' needs to maintain certain schedules. In another study like Gupta et al. (2008), Psaraki and Abacoumkin (2002) arranged the passengers into twelve segments, using combinations of residents (living in Athens/outside Athens residents) and foreign passengers, domestic and international travellers, and business and non-business travellers. Like others, Choo et al. (2013) also investigated the characteristics of business and non-business travellers. They identified that air passengers' demographic characteristics mostly affect non-business travel, rather than business travel, for the reason that most business travel is prearranged by the business organization. Therefore, no matter what characteristics a person may possess, the arrangement is made according to that organization's travel policy. On the contrary, non-business travellers themselves organize all essentials needed for a journey. As a result, the outcome of their decisions may vary depending on their characteristics. Roh (2013) has segmented the travellers in a different approach. The study considered departing (only the business and tourism) and non-departing (see off and welcome) travellers. Like the previous studies it also exposed that business travellers' VOT is higher than other air travellers, by approximately 2.5 times. In addition, he revealed that the VOT for the departing passengers is approximately 6.9 times higher than for the non-departing passengers. This seems obvious that departing passengers' arrival at the airport is related with on-time check-in, passing through security, finding the gate, boarding etc. which may make the departing passengers more time-conscious. Like Harvey (1986), Roh's study also did not consider rental cars or tourist buses as modal options. Finally, Chang (2013) developed a model only for the elderly passengers, who have considerable barriers to access the airport, which made them a segment to analyse separately.

In almost all of the studies it was found that private car is the most dominant mode to access at the airport (Roh, 2013; Ashford et al., 1996; Mandle et al., 2000; Akar, 2013; Alhussein, 2011). Especially business travellers are more likely to access by private car and prefer to park at the airport than non-business travellers. This would seem apparent because many business travellers are reimbursed by their organization. Similarly, business travellers also possess higher willingness to pay for the access (Koster et al., 2011). Apart from private car, taxi is another major mode for air travellers (Psaraki and Abacoumkin, 2002). In addition, despite their low use, rental cars, buses, trains, limousine services, tourist buses, and dedicated airport services must be considered for modelling every segment of air travellers. In another study, Castillo-Manzano (2010) considered passengers flying with a low cost carrier with those flying with a network carrier. The study revealed passengers choosing a

LCC are 6% less likely to travel by a taxi to the airport, but more than 4% more likely to drive a rental car and 2% more likely to use public transport than a passenger of a network carrier.

The market segmentation has played an important role to model airport ground accessibility in previous studies. Most of the researchers considered resident and non-resident, business and non-business travellers for modelling. Some of the researchers also considered domestic and international travellers as separate segments. Based on these segments, policy makers and operators can determine the appropriate models for their regions or airports. However, there are still many other segments which have been overlooked. For example, educational trips may be one important market segment, as there are many cities in the world that are based around universities and colleges. Moreover, for a low cost carrier-dominated airport, different fare classes (business or economy) or more social travel purposes could be potential market segments for future study. O'Connell and Williams (2005) found young and price-sensitive travellers have increased under the revolution of LCCs. Therefore, these types of air passengers' mode choice may be quite different from the traditional luxury airline travellers.

Based on a survey of travellers at Manchester Airport in the UK, Budd et al. (2014) did a very interesting study. They identified eight behaviourally separate groups of passengers, with varying perspectives to lessen car use, with attitudes constructed on some psychological theories. Among them, the conflicted greens and the pessimistic lift seekers are the groups with the most potential to change their mode choice for the greater good. This study showed that there is still a lot to know about the behaviour of air passengers' ground access from a behavioural perspective. In addition to that, Davison et al. (2014) obtained environment based segments of air passengers. The study identified four market segments such as: passengers highly believe air travel affects climate change and they have alternatives of air travel; passengers consider air travel has very low impact on climate change but they have alternatives of air travel; passengers think air travel has a high impact on climate change but do not think of alternatives; and, passengers consider air travel has a low impact on climate change but also considers very few travel alternatives.

Humphreys and Ison (2005) studied airport employee travel behaviour as part of the airport surface access strategies (ASAS) in UK. The study identified existing strategies that are implemented by different airport authorities and their targets to achieve government goals. However, no mode choice model was developed in the study. Moreover, no survey was conducted to capture the characteristics of the airport employees.

2.2 Key Variables

To date, there are numerous factors that have been taken into account to understand airport accessibility. Socioeconomic and demographic features, trip characteristics, available modal options, and road geographies are the most studied variables.

Harvey (1986) considered gender, household size, travel time, travel cost, income, trip purpose, number of pieces of luggage, and long-haul travel as the most significant parameters affecting access mode. Before Harvey, another group of researchers collected data in Baltimore-Washington airport, and exposed that trip purpose, travel cost and travel time are the most sensitive factors in passengers' airport ground access mode choice (Ellis et al., 1974). Skinner (1976), Monteiro and Hansen (1996), and Bao et al. (2015) also performed similar studies and found travel time and cost as the most significant parameters. In addition, Bao et al. (2015) found that trip purpose and number of pieces of luggage considerably affects the passengers' likelihood of choosing airport rail. As it is known that reliability of rail service is higher than that for other modes of travel, those who want a reliable service (e.g. business passengers) will prefer rail over other modes. They also found that a reduction in in-vehicle time will encourage more rail patronage. Apart from these

factors, for a new airport in Athens, Psaraki and Abacoumkin (2002) also studied factors such as trip origin, car ownership, taxi fare, occupation, time spent at the airport, and return home flight information.

Like others, Keumi and Murakami (2012) also found that travel time and travel cost are the two most important parameters. This is because on time arrival at the airport is the main objective of the air passengers' ground travel. Passengers often spend considerable money for an airline ticket, visa, and accommodation for a journey. Hence, it is a huge perceived economic loss if they miss the flight due to a late arrival at the airport. Passengers prefer reliable travel time to ensure they do not miss a flight. Additionally, travellers also prefer comfort, ease of access, luxury (limousine service), and safety in their travel to the airport. As a result, travel cost may vary considerably based on the amenities the passenger wants most. Moreover, they have considered waiting time, delay cost and service frequency. One interesting finding from the study was that passengers show more willingness to pay in the morning than in the afternoon.

Unlike other studies, Jou et al. (2011) performed their survey when a new access mode (TIA MRT) was under construction at Taoyuan International Airport (TIA) in Taiwan. They have considered three additional socioeconomic variables, namely job, education and number of motorcycles. The study revealed that students with individual monthly salary lower than NT$20,000 are prone to request their families or friends to drive them to the airport. Accompanying travellers, airline class (saloon, business, and economy), days away, and frequency of air travel are added trip characteristics they have considered. Frequent flyers are more prone to use private car as their mode of access, because frequent flyers are mostly business travellers and also their trip length is not that high. On the contrary, non-frequent flyers prefer to dropped-off and picked-up. However, the sample sizes for saloon and business class passengers were just 3 and 29. Therefore, the study was not able to distinguish much between these classes. Unlike others they found in-vehicle time and out-of-vehicle time are the most important parameters describing choice of access mode to the airport.

Ameen and Kamga (2013) also found in-vehicle time as a considerable variable. The study also considered factors like user friendliness, convenience of storing luggage, comfort, punctuality, safety, and speed as important factors. In a recent study based on Sari International Airport in Iran, Shafabakhsh et al. (2014) also considered many of the variables that Jou et al. (2011) used. In addition, they have studied time headway, construction and operation of the public transport system, and overall interest in the public transport system. From that study it was identified that safety is the major concern for passengers and construction and operation cost is of least concern. As may be obvious, in developing countries, safety and security is one of the substantial issues in selecting transportation mode especially public transport.

Family size or household size, driver's license and cost of gasoline, and trip origin have been studied by several researchers (Roh, 2013; Akar, 2013; Alhussein, 2011). The parking rate was considered by Gupta et al. (2008). Passengers will be discouraged to use private car when the airport parking price goes up.

Welch et al. (2015) investigated the correlation between ground accessibility and airport enplanements. Like previous studies he explored the peak and off peak hour travel behaviour to and from the airport. He obtained absolute and relative accessibility scores for two modes (auto and transit) and for peak/off-peak hours. Furthermore, he identified that the frequency of transit service, the density of areas covered by public transit (high or low density), the number of transfers, peak hour congestion, the size of the household, and the number of workers in the household have a significant effect on public transport accessibility to the airport.

In a different study, Koo et al. (2010) focused only on leisure travellers' arrival mode choice in Cairns, Australia. They obtained that 'sightseeing opportunities' and 'driver quality' are the significant variables for selecting a mode for leisure travellers. This study gives a great insight, showing that almost all previous studies of airport mode choice investigated departing passengers; however, there is a huge gap in the literature of arriving passengers. Most of the researchers stated that departing passengers' mode of access to the airport is the same as the arriving passengers. Nevertheless, arriving passengers' perception about ground accessibility may change after experiencing it physically. As stated by the study, sightseeing opportunities may be an important variable when a passenger arrives at a certain region, but may not be a significant variable when the same passenger departs.

Reliability is one of the major factors for air travellers. Nam et al. (2005) identified when passengers make mode selections, travel time reliability demonstrates a vital role. Tam et al. (2011) exposed the effects of reliability on air passengers' mode selections by using travellers' contentment as a latent variable. Effects of a safety margin in travel time were also included in that study. Tsamboulas and Nikoleris (2008) found that the most important factors for which passengers' willingness to pay increases are travel time and access mode. Comfort (convenience of carrying luggage) is the next most significant variable. Koster et al. (2011) also found that for higher travel time reliability, passengers want to spend more, because lower travel time reliability depicts a higher possibility of late appearance at the airport, leading to a higher chance of missing a flight. Tam et al. (2010) proved satisfaction plays an important role in selecting appropriate ground access modes.

In another study Chang (2013) revealed the requirements for elderly passengers. Apart from the general factors discussed above he also considered distance to the terminal, the space in the waiting area, comfort of the waiting area, a reasonable price, waiting time, and the opportunity that no transfer was needed in the travel mode. The study also suggested due to the increase in elderly passengers, more emphasize should be given to fully comprehend the basic needs of those passengers. Moreover, different segments of the aging population could provide potential avenues for future research.

Ryley et al. (2013) did a very fascinating study about reducing vehicle generated trips. The study suggested that, by familiarizing passengers with the telepresence system at the airport, drop-off and pick-up trips can be reduced. In addition, ride sharing may be integrated into the airport ground access strategy. A radio frequency identification (RFID) system may be installed in trains and coaches for ease of luggage handling. Moreover, detailed study is needed to comprehend the behaviour of air passengers and potential transit users. To categorize different behavioural segments Davison et al. (2014) considered several new factors. The impact on climate change and alternative modes of air travel were investigated in their study. Subsequently a number of behavioural parameters were also explored. Insights on selecting an energy-efficient airline, spending a holiday in Britain rather than overseas, reducing use of energy at home, helping to reduce emissions, and realising environmental constraints may be a threat in the future, were explored.

The mode choice for access to airports also depends on the airport and airline. The departure airport, airline, aircraft type, on-time performance, and attributes of rail service may have substantial effect on airport ground access (Hess et al., 2013). If all other variables are constant between two airports, accessibility will be the only determinant in selecting airports. In contrast, the departure airport may influence a passenger to select certain modes. Therefore, it is prerequisite for operators to understand the current travel conditions in a region to predict or forecast air passenger demand as well as ground access demand.

From the above literature it is been portrayed that many parameters of airport ground access were investigated in the last few decades. Nevertheless, various avenues still have not

received adequate attention by researchers. The psychological aspects of air passengers should be examined more meticulously, perhaps as latent variables influencing access decision-making. In addition, information should be another weighty factor in taking certain modes. To our knowledge, there has not been enough attention given on how the availability of information dictates one's mode selection, particularly for those who may not be frequent travellers of an airport. For example, most passengers now carry smartphones while travelling. In 2013, the number was 76% (SITA, 2013). In a study, 31 European airport's iPhone Apps were evaluated and found that the apps helped very little to plan and book a trip; rather, it was more widely used to provide parking information and services (Martin-Domingo and Martin, 2015). Consequently, those apps definitely will encourage travellers to use private car and parking. However, the focus should be given on the types of information that actually are responsible for a sustainable mode choice. Advertisements, mobile apps, websites, and suggestions from friends and family may influence one's mode choice. Moreover, there has been few researches how weather conditions and seasonal variation affects passengers' mode choice. Therefore, more detailed exploration is necessary for these parameters.

2.3 Mode Choice Models

In order to forecast the ground access demand, mode choice models have been developed for numerous airports in the last few decades. To capture the demand as accurately as possible, researchers have investigated various market segments and explanatory variables. Though, to date no "standard" model exists that incorporates these explanatory variables and segments consistently. In terms of methods, in the last forty years a shift has been observed from the multinomial logit model (MNL) to the more complex nested logit model (NL). During the 1970s, researchers favoured MNL models for airport ground access. However, with the advantages of NL over MNL (Ben-Akiva and Lerman, 1985) the transfer towards NL in state-of-the practice has been observed. Since then, mode choice models have shifted towards more complex Cross Nested Logit (CNL) and Mixed Logit Models (MXL) to capture more complex error structures.

One of the earliest studies on airport ground access mode choice in the Baltimore-Washington region by Rassam (1970) used MNL for analysis. Similar to this, many other researchers also used MNL for predicting airport ground access demand (Sobieniak et al., 1979; Spear, 1984; Gosling, 1984; Harvey, 1986). Sobieniak et al. (1979) studied the mode choice for intercity terminals integrating airports, in Ottawa-Hull, Canada, and Spear (1984) focused more on airport bus services at Washington National and Dulles International airports. In another study, Skinner (1976) used MNL for airport choice among Friendship International Airport, Washington National Airport, and Dulles International Airport. However, Harvey (1986) did a rigorous analysis for business and non-business travel to understand ground access mode for local residents in the San Francisco Bay Area.

With the evolution of NL models, Harvey (1988) used NL models to analyse the airport access and airport choice for the San Francisco Bay Area. Later Furuichi and Koppelman (1994) used both NL and MNL in their study and found that the NL explains the observed behaviour better than the MNL models. Afterwards, some other studies also focused on NL, such as Harrington et al. (1996) and (Portland Metro, 1998). Pels et al. (2003) and Monteiro and Hansen (1996) used a two level nested logit model with the airport choice at the top level and the access mode choice at the lower level. Similarly, Gupta et al. (2008) developed a two level nest in the same manner. However, they found that the MNL is more statistically significant than NL. Gosling (2006) indicated that all the two-level nested logit models could be considered as MNL models since they considered ground access modes in a single nest. In addition, Psaraki and Abacoumkin (2002), Tam et al. (2011), and Roh (2013) considered MNL for analysis.

Apart from these traditional NL and MNL models, some other studies used different modelling techniques. Chebli and Mahmassani (2003) used ordered probit model to reveal the air passengers' willingness to embrace new modes that may lessen congestion around airports. A web-based stated preference (SP) survey was conducted for that study. Using both stated preference (SP) and revealed preference (RP) data, Jou et al. (2011) investigated mode choice behaviour in Taiwan. They used a mixed logit model (MXL) for analysis. By using incremental logit (or pivot point logit), Ameen and Kamga (2013) predicted airport ground access and egress trips at John F. Kennedy International Airport (JFK). Hess et al. (2013) also investigated the demand forecast for airline, airport and access mode by using cross-nested logit models (CNL). In order to capture passengers' satisfaction with ground access modes, structural equation modelling (SEM) was used by Tam et al. (2010). Chang (2013) used logistic regression analysis to comprehend the airport access behaviour of elderly passengers in Taiwan.

The above literature draws a basic framework of the history of ground access mode choice models. Almost all of the models were analysed based on the data collected by stated preference (SP) and revealed preference (RP) survey data. Most of the models had limitations in terms of data collection; small sample sizes and challenges in collecting data when passengers were in hurry (before security or immigration) were the most common challenges. However, to forecast the access demand as accurately as possible, data collection must be performed without time or sample size limitations. Additionally, the application of newer model structures, such as cross-nested logit (CNL) and mixed logit models (MXL) may need to be more carefully considered to analyse airport ground access.

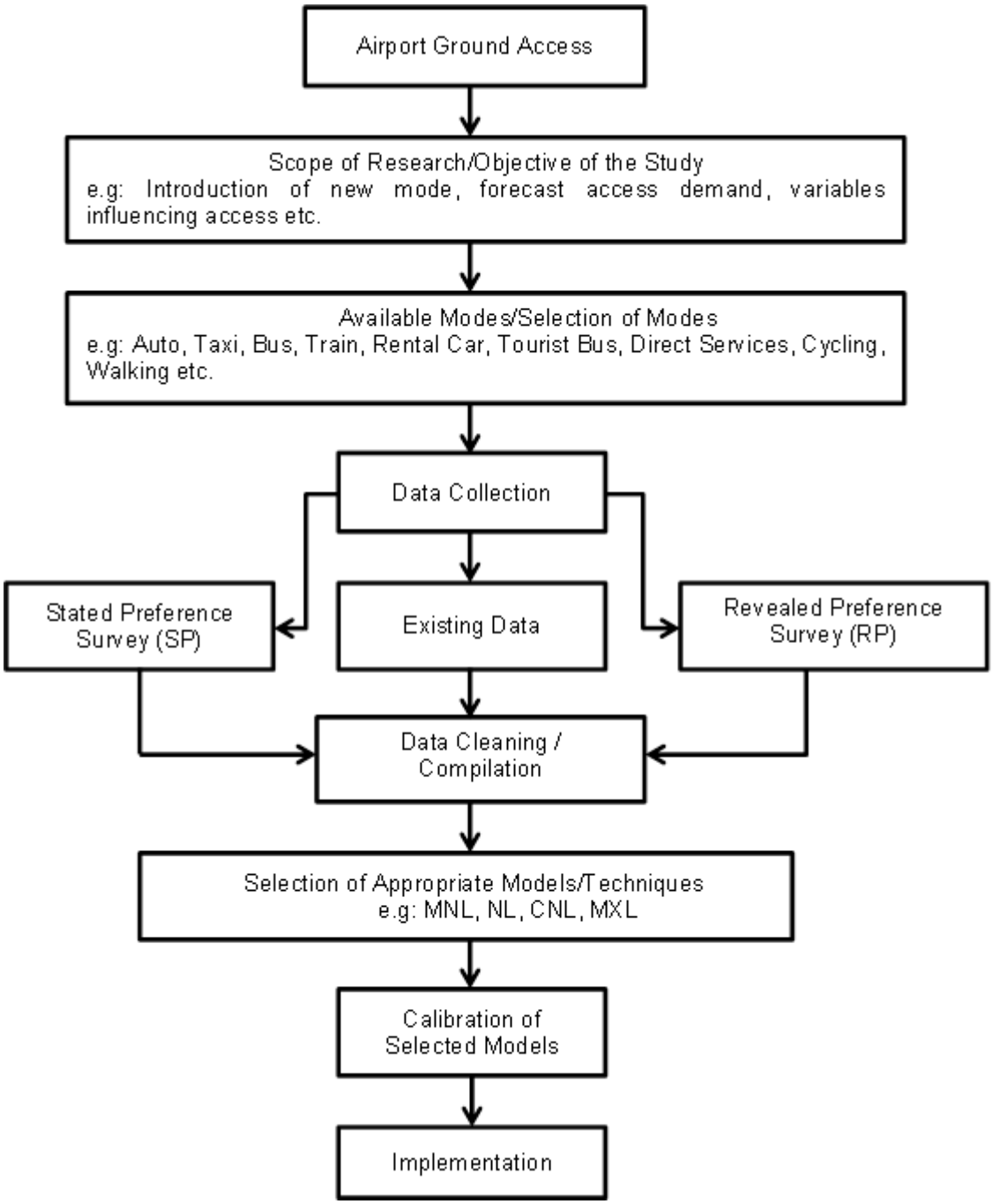
3. General Framework for Airport Ground Access

Due to diverse socioeconomic and demographic features around the world, it is truly difficult to fashion a universal framework for analysing ground access behaviour. In addition, airports have numerous priorities in serving passengers, based on their geographic location and diverse passenger segments. However, a general framework can be drawn from the previous studies and is shown in Figure 1.

The framework suggests several steps/tasks for the airport ground access study. After defining the objective of the research, available modes and market segments need to be determined. Based on the modes and market segments, data should be collected and cleaned for the analysis. Generally, data is collected through stated preference (SP) and/or revealed preference (RP) surveys. If needed, existing data is also incorporated. Later on, appropriate models need to be selected for the analysis. Calibration of selected models is one of the important tasks of the general framework. Once the analysis is done, calibration is performed to verify the acceptability of the models. Acceptable results from the analysis are incorporated by the policy makers and airport operators to plan airport access.

However, the framework is not as detailed as needed. The selection of models or techniques may be quite cumbersome and needs more detailed description. Moreover, explanatory parameters may vary widely from region to region and not all modes are available in a particular region/airport. Nonetheless, this framework can be used as starting point for analysing the behaviour of air passengers' access to and from the airport.

Figure 1: Airport ground access framework



4. Conclusions

This paper presents an analysis of the previous studies on airport ground access. It has been understood from the previous literature that airport ground access mode choice models are not as straightforward as traditional travel demand models. Therefore, this field deserves further study. The future avenues of research may be diverse, as previously discussed. A few of these avenues are summarised below:

- There are various market segments that have not been investigated yet, such as: access to low-cost carrier-dominated airports, behaviours of people in different fare classes, and the effects of social visits and educational trips.

- Airport access among different segments of the aging population could be a potential avenue for future research.

- New explanatory variables may be included in the modelling framework, such as the impact of weather conditions and information in selecting a mode for airport access.

- Like NL and MNL models, more complex logit models need to be considered. Therefore, the usability of those models warrants more attention.

- Arrival passengers' characteristics should be considered in a more detailed manner when considering travel from the airport.

- Very little research has been done to comprehend air passengers' mode choice in an Australian context. Despite the huge demand of air passengers, no complete study on air passengers' ground accessibility is found for any airports in Australia. Therefore, policy makers, transport planners, and researchers need to investigate the behaviour of air passengers' mode choice for better and sustainable transport planning.

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