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Public Transportation: Airport – City Link

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ABSTRACT

The airport is a set of technical and commercial infrastructures to the operation of air transport. The air transport has the objective to facilitate the movement of people and cargo between distant places or just because of the fast way. As a trip generator pole, it requires specific transportation systems to join the airport and the city in order to disperse or attract the demand. Therefore this article aims to present an overview of the availability of public transport as a city-airport link to various airports and a mathematical model obtained by a linear regression, using variables such as passenger traffic, population and number of parking spaces at the airports.

Keywords: Air transport, Airports, Public Transport

INTRODUCTION

Air transport have important role in shaping the economic, political and social scenario for the population they serve. Contribute mainly to the economic sector by creating jobs, stimulating the industry and tourism. Generate revenue for hotels, restaurants, retail stores, sightseeing, rental cars and others, and increases the government revenues through the local taxes.

Considering just as a mean of transportation, the air transport has the objective to facilitate the movement of people and cargo between distant places or just because of the fast way.

According to Kazda the primary advantage of air transport is speed, particularly for long haul where it has completely supplanted shipping, but also for those short haul trips where it is in competition with surface transport. However, the average speed is reduced by the ground portion of the trip. The trip does not start or finish in the airport, but at home, at the hotel, at the workplace etc. The passenger is just as concerned to reduce time on the ground as in the air part of the trip, and just as annoyed by any delay, whether in the air, the terminal or on the way to and from the airport. The total time of transportation 'from door to door' is decisive for the passenger. The attractiveness of an airport markedly decreases if the time of access by surface transport exceeds a certain maximum time. For short haul trips this might be as short as 30 minutes, while two hours or more might be acceptable for long haul, inclusive tour or low cost carrier trips.

The quality of surface transport affects the size of the catchment area of the airport in the competitive market between several airports. Surface transport quality and quantity should not need to become a limiting factor of the development of air transport at an airport if plans have been properly developed.

A gradual increase in the share of the available high occupancy modes of transportation normally occurs as the airport grows, and this change should be encouraged on the grounds of environmental impact and balanced capacity. Car trips will always predominate at small airports. Growth in the share of high occupancy vehicles as the traffic increases will normally take the form of public (mass) road transportation at moderately sized airports, while high capacity rail transportation should have a substantial share in the large airports. Public transportation should have some role by the time an airport reaches 2 million passengers per year (mppa), including airport workers who do not always have access to a car. Many factors make the car the preferred mode of access for passengers, including the low marginal cost, the convenience for carrying bags and family groups, and the instant availability. It is therefore not easy to get people to move to high occupancy modes even if they are competitively priced, frequent, reliable and form part of a transport network that allows access to the complete catchment area. The airport administration has a new role to ensure that the passenger can get to and from the airport quickly, easily and simply so that they do not miss their flight. If the management does not do this, some potential passengers will be lost to other airports or other modes of transport. Surface transport must be considered as a part of the 'product' of the airport. Managers have to work to fulfil the airport's access needs by encouraging the local authorities and transport operators to respond by investing in roads and operating services.

According to Kazda, theoretically it would be possible to ensure the change in the share of individual modes by making the mass transportation more attractive or by making the private transportation less attractive by imposing road tolls, high parking fees etc. However, individual groups of people accessing the airport, who will mostly be passengers and those accompanying them, employees or visitors to the airport, will all rank the factors differently. The following factors can be identified as affecting the selection of the mode of transport:

- the availability of the mode
- the distance of the airport from the home or workplace
- duration of the individual elements of the transportation process (waiting, time to access the mode of transport, transportation time, time from the mode to the airport check-in)
- standard of comfort and quality of transport, which includes ease of use, number and quality of
- seats, handling of baggage, number and difficulty of transfers en route, possibility of secure parking
- reliability of transport
- total generalised cost of transportation (parking fees, value of time etc. must be included as well as fares or marginal cost of using private transport)
- other factors such as personal safety, privacy, flexibility.

Research shows that the decisive factors for passengers are: price, transportation time, number of changes and baggage handling. For airport employees particular concerns are flexibility, availability and personal safety for shift patterns out of normal hours.

Kazda says that airport access is needed not only by the airline passengers but also by other important groups of users. The number of employees who daily commute to the airport represents one quarter to one half of the daily number of airline passengers at medium size and large airports. In addition there are the accompanying persons (meeters and greeters) who in some countries outnumber the passengers, and the visitors to the airport, this latter category amounting to 5 or 10 per cent of the total. The roads and public transport networks also have to cater for the needs of the local nonairport traffic. It is necessary to emphasise that there are also other factors which distinguish the airline passengers from other groups of surface transport users that have often a decisive effect on the selection of the kind of transport provided, and these can be different in each case. Therefore it is necessary to distinguish categories of passengers using surface transport, characterised by the factors such as:

- the reason of the trip to the airport
- type of flight (scheduled – charter, short haul - long distance flight)
- duration of the stay
- social and economic factors (income, age, occupation, size of household, car ownership)

LITERATURE REVIEW

AIRPORT GROUND ACCESS

According to TRB (2010) ground access facilities at airports are the interface between the airport terminal(s) and the surrounding region. As such, planning for these facilities cannot exist in a vacuum. Coordination is required on the part of local, state, and federal governments from airport planning and operations representatives; local and state highway and transit officials; and private transportation providers who utilize airport facilities.

Ground access transportation planning at airports occurs on both a regional and a local scale. Regionally, the projected future needs of airport users must be taken into account during long range planning processes and the strategic aspects will normally be considered in some depth during the Airport Master Plan development process. At a more detailed level, connections between components of the airport facility must be planned and designed to accommodate the expected traffic flows.

COORDINATION AND PLANNING OF GROUND ACCESS INFRASTRUCTURE

According to Wells, to effectively develop ground access requirements to the airport from the CBD and suburban areas, it is important to gain an understanding of the geographic region from which passengers access the airport. This region is known as an airport's capture area. For commercial service airports, the geographic size of a capture area varies greatly, depending primarily on the population density in the region and the availability and cost of air carrier service from the airport, as well as from other airports within the region. General aviation airports typically serve more local areas, such as one CBD, suburban area, or outlying community. Many communities fall into multiple airport capture areas illustrating the fact that passengers in fact choose to access different airports from the same region on the basis of the characteristics of each airport, offered air service, and the ground access system. Although not the most significant determinant of passenger volumes, the ability to access one airport over another indeed has an effect on which airport a passenger will choose to use. The ability of airport planners and managers to identify the airport's capture area and coordinate an effective ground access system from within the capture area to the airport is vital to the ultimate success of the airport.

According to TRB (2010) the data collection and evaluation phases lead into the development of a ground access plan. The flowchart in Figure 1 depicts the process of developing a ground access plan. The existing ground access conditions, together with the Airport Master Plan, form the basis for developing a ground access plan. The data collected on ground access facilities can be analyzed to determine existing deficiencies in the ground access system. Based on the Airport Master Plan, alternatives for improvements to the ground access system can be developed.

Future air passenger demand for the target analysis year can be used to "grow" existing traffic volumes to future levels. Based on the future traffic volumes, the alternatives that have been developed can be evaluated to determine if they will meet the needs of airport users or if additional deficiencies exist. The alternatives can then be refined, and a preferred alternative selected that will have the capacity to handle expected future traffic volumes, while fitting in with the future plans for the airport.

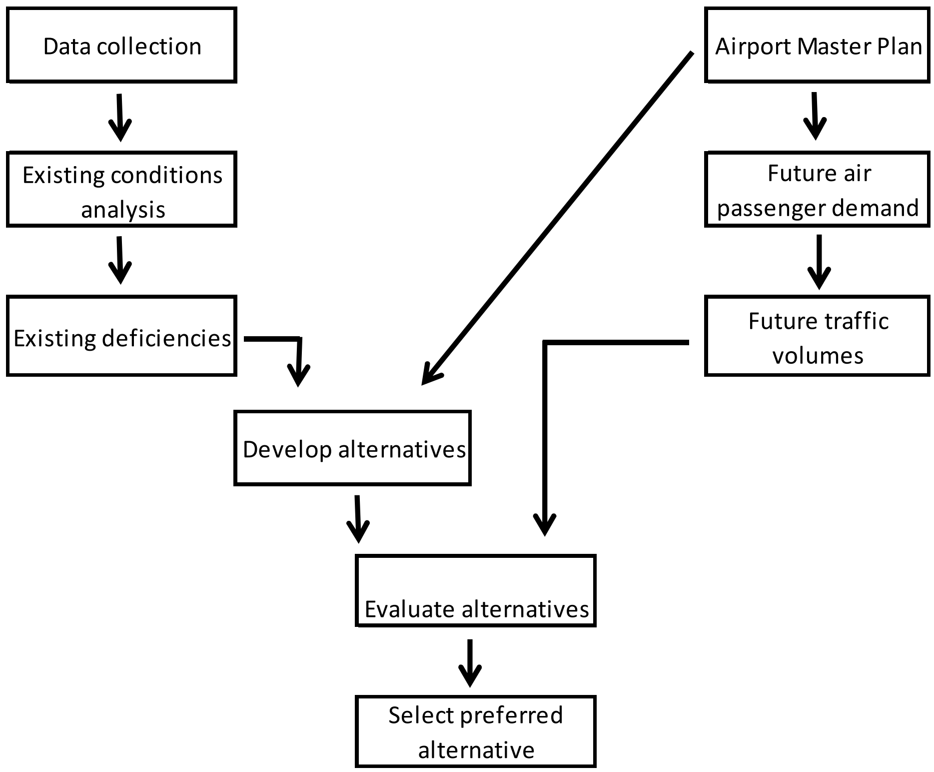

Figure 1: Flowchart to develop ground access plan.
Source: TRB (2010) – ACPR

ACCESS MODES

Automobile

According to Ashford the attractiveness of the mode stems from its great flexibility, with the strong convenience factor of direct origin-destination movement, especially where the air traveller is encumbered by large amounts of baggage or is accompanying elderly or handicapped persons or young children. Overall access journey speeds are potentially high, especially where the nonairport end of the trip is not located in the central city area; when parking at the airport is required for relatively short periods, journeys can be made relatively inexpensively by auto. This is especially true where there is more than one air traveller in each car.

The principal disadvantage of this mode is the high degree of surface congestion caused by individual cars on access routes, the high interaction with nonairport traffic, and the associated high level of parking infrastructure required at the airport. The mode can also be unreliable when congestion builds up, causing jams or slow-moving traffic flows along access routes. Since airport access by auto shares the general surface transport infrastructure, this mode is vulnerable to delays caused by traffic that is not associated with the airport. Parking in the immediate vicinity of some major airports is often so expensive that most long-term parkers are forced to use cheaper remote parking outside the airport boundaries. Use of such parking can materially affect access times and may seriously lower the level of convenience afforded by the overall access mode. Parking costs can be so great at airports that for some air travellers the cost will affect the choice of access mode.

Taxi

According to Ashford taxicabs are a frequently used mode of access to airports, especially where the airport attracts a high proportion of business traffic and the distance between airport and central city is not high. Being direct from origin and destination, with easy baggage handling, the mode offers a high level of convenience. Under most conditions, the overall trip speed is high, and, if several people travel together, the cost per capita can be considerably lower than for single cab occupancy. In general, however, the taxicab mode is relatively expensive for the single traveller. Moreover, since taxis must share the existing road transport infrastructure, they are also vulnerable to surface congestion from nonairport traffic, and the trip may be slow.

According to Kazda although the airport administration is not directly responsible for the operation of taxis, the bad impression formed from low-quality or poor value taxi service have an impact on the overall image of the airport. Therefore the airport administration should lay down criteria for the acceptable operation of taxis. Important factors are:

- to ensure the number of taxis meets the demand, particularly at night and in the time when the mass transportation is not available
- to ensure the high quality and fair price of services
- to deal with security issues in some countries and to discourage unofficial operators.

Shortage of taxis can occur particularly at smaller airports when two flights are arriving close together. The problems of shortage of taxis and quality of service are mutually interdependent. This is often solved by awarding licences to serve the airport for a limited period of time.

Bus

According to Ashford the urban service can provide a high level of convenience for airport staff. From the viewpoint of the air traveller, the mode is less convenient. Routing can be difficult, especially in a strange city, and manoeuvring luggage in the presence of peak loads of nonairport passengers is demanding at best. Urban buses are recognizably delayed by urban congestion; frequently, the scheduling and routing of the bus system is not particularly responsive to the needs of air travellers. Overall travel speeds are usually low because of frequent stops, and in general the service is bad.

According to Kazda, several types of bus service to airports can be distinguished.

- Normal scheduled services of the local metropolitan authority are used more by employees than passengers because of their frequent stops and poor provision for luggage.

- Local shuttle coaches dedicated to airport passengers. However, they usually link the airport only with the municipal rail or bus terminals and the major hotels. They work well for visitors, but are less convenient for locally based travellers who are more likely to want to start or finish their trip from their homes in the suburbs.
- Longer distance scheduled coach services compete with rail, taxi, private car or even air access to hub airports from more distant cities whose own airport does not offer the same range of air services. They overcome the need for the change of mode that is required on most rail systems to complete an airport access trip, but tend to be slow, infrequent and, as with the shuttle coaches, they may suffer from delays due to road congestion.

BRT

Bus Rapid Transit (BRT) is a high quality bus-based transit system that delivers fast, conformable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service.

Railway Transport

According to Kazda the recent political push for a sustainable transport system, combined with road congestion and frequent delays, has caused a renaissance of public transport in accessing airports. Many airports are supporting increased use of rail transportation, both to serve the nearest cities and also to increase their catchment, to the extent that airport expansion has been made conditional on achieving targets of up to 50 per cent of passengers using public transport.

The decision to connect the town and the airport by rail transport depends on several factors, particularly:

- volume of airport passengers per year
- possibilities of connection to the existing transport infrastructure
- split of traffic between scheduled, charter, business and leisure passengers.

Train

According to Ashford conventional rail service, often direct, offers good rapid connection with the city center, as well as overall speeds higher than those provided by urban rapid transit systems having numerous and unavoidable station stops en route. Of great benefit, however, is the availability of service that does not entail additionally obtrusive transport infrastructure.
Conventional rail systems often give relatively poor overall access time in spite of good line speeds because of the infrequency of scheduled departures. In addition, use of the service usually requires departure from the central city; therefore, only the central area is well served by this mode. Furthermore, baggage-laden air passengers encounter some difficulty at central railway stations when mixed with other passenger traffic, including commuters at

peak hour periods. Finally, the rail mode satisfies the access need only partially, since another trip, by taxi or other means, if frequently required to get the traveller to and from the rail station. Conventional rail systems have proved to be most satisfactory where the in-town terminus provides easy access to an extensive urban distribution system: taxi, bus, or urban rapid transit.

Metro

According to Kazda the underground or metro systems are characterised by short distances between frequent stops. The underground is mostly suitable for the employees and for people with business at the airport. Its advantages are high frequency and low cost. The disadvantages are that it is relatively slow and not suitable for the transportation of larger pieces of baggage.

Light Rail

The Light Rail (LRT) is a form of rail transportation of average capacity. The light rail systems are generally cheaper to construct than, for example, a subway or a train. Besides, those have greater flexibility in tight corners. The light rail vehicles are used in various cities around the world, as they allow you to carry a greater number of people than any bus. They produce less pollution and noise, in many cases are faster and are easier to evacuate in an emergency than other means of transport.

HIGH SPEED

According to Ashford despite differences in performance characteristics and in kind, specialized rail systems and high-speed ground transport systems can be discussed simultaneously in terms of advantages and disadvantages. Inherently, their functional characteristics are similar as far as the airport link is concerned. The attraction of specialized rail systems is simply stated. Their attraction lies in their ability to provide rapid, non-stop, reliable service between the central city and the airport terminal at level of comfort and convenience matching the air trip itself.

On careful examination, however, the disadvantages associated with high-speed dedicated systems become manifest. Such systems are likely to be very expensive, either overtly in the form of high fares, or covertly in the form of heavily subsidized total costs. Furthermore, systems, as proposed or designed serve only the central city reasonably well; they therefore attract passenger traffic by other modes into the already congested city center. Transfer between other feeder and distribution systems at the central city terminal faces the baggage-impeded traveller with linkage problems with other modes.

Parking space at airport

According to Ashford one of the greatest difficulties related to access is the determination of the location and number of parking spaces. Parking demand is a complex function of the number of persons accessing the airport, the available access modes, the type of air traveller, the parking cost, and the duration of the parking period, which is determined by the type of person making the trip (i.e., traveller worker, service personnel, or visitor). Demand from the travellers must be further categorized into business, leisure, long term, short term, and so on. It was noted earlier that air travellers may represent a minority of those entering the airport; the majority of the airport population may be visitors and workers.

Considering FAA (1988) the generally accepted definition for short-term parking is anything less than three hours. Approximately 70 to 85 percent of all parking lot users are short-term parkers, mainly greeters and well-wishers. However, this amounts to full time use of only 20 to 30 percent of the total parking requirements. Long-term parkers, the remaining 15 to 30 percent of parking lot users, are almost all travelers and occupy 70 to 80 percent of the available parking spaces. Through actual surveys and analysis of parking stubs conducted over several consecutive days, utilization charts can be developed showing vehicle volumes and length of stay. Short-term parking is usually provided nearest the terminal, since its turnover rate is often at least three times that of long-term lots. Short-term rates are high to discourage long-term parkers from clogging close in lots. A rule-of-thumb suggests that separate short and long-term parking should be provided when the total annual passenger volume exceeds the 150,000 to 200,000 range.

Unconventional Means of Transport

According to Kazda unconventional means of transport for transportation between the town and the airport may include different types of elevated railway systems, monorail systems, magnetic levitation (maglev) trains, air-cushion vehicles, and helicopters etc. Some airports as Brussels, Sydney and London Heathrow have cycling track as an option to the users.

FACTORS INLUENCING DEMAND FOR GROUND ACCESS

According to Wells, demand for ground access, that is, the volume of people that wish to have access between the airport and their respective origins and destinations at commercial service airports, is primarily generated by the number of enplaning and deplaning passengers using the airport. These volumes are generated in part by the provision of air service by the air carriers that serve the airport. Characteristics of this air service include destinations served, the type of aircraft used, and the daily departure and arrival schedules of the air carriers. In addition to passengers themselves, airports are accessed by those people seeing off or meeting passengers at the airport. These people are known as meeters/greeters. The demand for airport access by meeters/greeters is dependent on similar characteristics as that of passengers themselves. A significant proportion of trips made to and from airports are generated by the workforce in place at each airport, including airport, airline, and government employees, as well as employees of the many private companies that do business at the airport, including concessionaires, contractors, and suppliers. These trips are less dependent on available flight service. They are more associated with the travels that occur during any business day, including morning and evening commutes and trips associated with business delivery. In addition, as many functions in the airport operate as much as 24 hours per day, there are a number of trips to the airport that occur outside normal business hours.

METHODOLOGY

This paper has the objective to present an overview of the availability of public transport as a city-airport link to 10 airports from different range of passenger traffic: airports that operate from 5 to 10, over 10 to 15, over 15 to 20, over 20 to 40 and over 40 million passengers per year. For each airport a series of data are collected and analysed, such as: the total number of passengers carried; the domestic and international traffic (in the years 2010 and 2011); the availability of public transport; the distance between the airport and the city reference and the population density of each area.

The data for this study was obtained by selecting airports that publish their characteristics and statistics on the internet and is located in different parts of the world.

For each airport selected, we gathered the following data:

a) Passenger movements: total, international and domestic for the years of 2010 and 2011.
b) Public Transport: is selected the access mode that exists to an airport.
c) City distance: distance between the airport and the reference city center (km).
d) Population: Population in the area where the airport is located.
e) Demographic density (hab/km^2).
f) Parking Spaces: number of car parking spaces available.
g) Variety of parking lots: the “X” represents the existence of different types of parking lots, as for short or long term and “No” if the isn’t this variation available.

We chose 50 airports in different continents of North America, South America, Europe, Asia and Oceania, namely:

For airports that have between 5 and 10 million passenger movements: Budapest Airport (BUD – Europe), London Luton Airport (LTN – Europe), Santos Dumont Airport (SDU – South America), Pulkovo Airport (LED – Europe), Porto Airport (OPO – Europe), Confins International Airport (CNF - South America), Sacramento International Airport (SMF - North America), Adelaide Airport (ADL – Oceania), William P. Hobby Airport (HOU - North America) and Milano Linate Airport (LIN – Europe).

For airports that have over 10 to 15 million passenger movements: Rio de Janeiro International Airport (GIG - South America), Lisbon Airport (LIS – Europe), Athens International Airport (ATH – Europe), Auckland Airport (AKL – Oceania), Montréal-Dorval International Airport (YUL - North America), Brasilia International Airport (BSB - South America), Malaga Airport (AGP – Europe), Santiago International Airport (SCL - South America), Geneva International Airport (GVA – Europe), and Ben Gurion International Airport (TLV - Middle East).

For airports that have over 15 to 20 million passenger movements: Vancouver International Airport (YVR - North America), OR Tambo International Airport (JNB – Africa), São Paulo / Congonhas Airport (CGH - South America), Brussels Airport (BRU – Europe), Milano Malpensa Airport (MXP – Europe), Helsinki Airport (HEL – Europe), San Diego International Airport (SAN - North America), London Stansted Airport (STN – Europe), Gimpo International Airport (GMP – Asia) and Brisbane Airport (BNE – Oceania).

For airports that have over 20 to 40 million passenger movements: São Paulo/Guarulhos International Airport (GRU - South America), London Gatwick Airport (LGW – Europe), Toronto Pearson International Airport (YYZ - North America), Rome Ciampino Airport (CIA – Europe), Atatürk International Airport (IST – Europe), Miami International Airport (MIA - North America), Munich Airport (MUC – Europe), Sydney Airport (SYD – Oceania), Incheon International Airport (ICN - Asia) and Copenhagen Airport (CPH – Europe).

For airports that have more than 40 million passenger movements: Dubai International Airport (DXB - Middle East), Paris-Charles de Gaulle Airport (CDG – Europe), John F. Kennedy International Airport (JFK - North America), Beijing Capital International Airport (PEK – Asia), London Heathrow Airport (LHR – Europe), Hartsfield–Jackson Atlanta International Airport (ATL - North America), Madrid-Barajas Airport (MAD – Europe), Hong Kong International Airport (HKG – Asia), Singapore Changi Airport (SIN – Asia) and Dallas/Fort Worth International Airport (DFW - North America).

The next section presents a proposed method using the data gathered on each airports and analysis of comparisons between them.

Table 1 summarizes the characteristics of the airports analyzed.

Passeng. Mov. (million)	Airport	Number of passengers: Total 2010	Total 2011	International 2010		International 2011		Domestic 2010		Domestic 2011		Public Transport: Bus	BRT	LTR	Subway	Train	High Speed Train	City distance (km)	Pop. (million)	Demog. density (hab/km²)	Parking spaces	Variarty of parking lots
5 to 10	Budapest Airport (BUD)	8,190,089	8,920,653	8,190,081	100%	8,920,211	100%	8	0%	442	0%	X	-	-	-	-	-	16.0	1,74	3,300	2.500	X
	London Luton Airport (LTN)	8,734,000	9,510,000	7,809,716	89%	8,273,700	87%	941,915	11%	1,236,300	13%	X	-	-	-	X	-	52.0	8,27	5,200	6,749	X
	Santos Dumont Airport (SDU)	7,822,848	8,515,021	0	0%	0	0%	7,822,848	100%	8,515,021	100%	X	-	-	-	-	-	1.0	12,60	5,348	1.042	No
	Pulkovo Airport (LED)	8,443,753	9,610,767	4,387,017	52%	5,128,337	53%	4,056,736	48%	4,482,430	47%	X	-	-	-	-	-	15.0	4,87	3,390	1.851	X
	Porto Airport (OPO)	5,283,361	6,003,408	4,438,699	84%	5,155,441	86%	844,662	16%	847,967	14%	X	-	-	X	-	-	11.0	2,29	5,702	3.000	X
	Confins International Airport (CNF)	7,261,064	9,534,987	301,487	4%	422,402	4%	6,959,577	96%	9,112,585	96%	X	-	-	-	-	-	40.0	5,18	7,177	1.538	No
	Sacramento International Airport (SMF)	8,850,239	8,718,817	69,921	1%	67,834	1%	8,780,318	99%	8,650,983	99%	X	-	-	-	-	-	16.0	2,52	1,861	16.000	X
	Adelaide Airport (ADL)	7,152,477	7,396,838	586,990	8%	592,619	8%	6,565,487	92%	6,804,219	92%	X	-	-	-	-	-	6.0	1,23	1,295	3.000	X
	William P. Hobby Airport (HOU)	9,054,001	9,843,302	0	0%	0	0%	9,054,001	100%	9,843,302	100%	X	-	-	-	-	-	11.0	2,09	1,505	4.060	X
	Milano Linate Airport (LIN)	8,295,436	9,061,749	2,795,561	34%	3,488,773	39%	5,499,874	66%	5,572,975	62%	X	-	-	-	-	-	7.8	5,20	7,400	5.000	X
10 to 15	Rio de Janeiro International Airport (GIG)	12,337,944	14,952,830	3,127,059	25%	3,741,362	25%	9,210,885	75%	11,211,468	75%	X	-	-	-	-	-	20.0	12,60	5,348	4.310	No
	Lisbon Airport (LIS)	14,066,545	14,790,242	11,942,431	85%	12,763,256	86%	2,124,114	15%	2,026,986	14%	X	-	-	X	-	-	7.0	3,00	6,531	7.000	X
	Athens International Airport (ATH)	15,400,000	14,400,000	9,800,000	64%	9,500,000	66%	5,600,000	36%	4,900,000	34%	X	-	-	X	X	-	30.0	3,07	1,276	7,160	X
	Auckland Airport (AKL)	13,713,378	13,703,043	7,600,956	55%	7,634,349	56%	6,112,422	45%	6,068,694	44%	X	-	-	-	-	-	20.0	1,40	710	6.730	X
	Montréal-Dorval International Airport (YUL)	12,969,834	13,660,862	4,856,275	37%	5,232,678	38%	4,963,692	38%	5,224,697	38%	X	-	-	-	X*	-	20.0	3,82	4,517	11.500	X
	Brasilia International Airport (BSB)	14,347,061	15,398,737	201,684	1%	384,392	2%	14,145,377	99%	15014345	98%	X	-	-	-	-	-	11.0	2,57	441	1.034	No
	Malaga Airport (AGP)	12,064,521	12,823,117	9,497,191	79%	10,135,875	79%	2,567,330	21%	2687242	21%	X	-	-	-	X	-	8.0	1,06	1,400	2219	X
	Santiago International Airport (SCL)	10,311,349	12,105,524	5,013,867	49%	5,573,411	46%	5,297,482	51%	6532113	54%	X	-	-	-	-	-	16.0	6,00	8,464	4000	X
	Geneva International Airport (GVA)	11,880,397	13,130,222	11,315,785	95%	12,571,893	96%	564,612	5%	558329	4%	X	-	-	-	X	-	5.0	0,47	12,094	5.935	X
	Ben Gurion International Airport (TLV)	12,160,339	12,978,605	11,345,596	93%	12,226,023	94%	814,743	7%	752,582	0%	X	-	-	-	X	-	19.0	3,15	7,867	11,300	X
15 to 20	Vancouver International Airport (YVR)	16,778,774	17,032,742	3,863,419	23%	3,992,322	23%	8,781,417	52%	8,875,301	52%	X	-	-	-	X	-	12.0	2,30	5,249	6.200	X
	OR Tambo International Airport (JNB)	18,643,145	19,004,001	7,965,594	43%	8,088,488	43%	10,677,551	57%	10,915,513	57%	X	-	-	-	X	-	25.0	7,15	2,000	11.500	X
	São Paulo / Congonhas Airport (CGH)	15,499,462	16,756,452	0	0%	0	0%	15,499,462	100%	16,756,452	100%	X	-	-	-	-	-	8.0	20,30	7,383	3.369	No
	Brussels Airport (BRU)	17,180,606	18,786,034	17,180,606	100%	18,786,034	100%	0	0%	0	0%	X	-	-	-	X	-	12.0	1,80	7,025	12.000	X
	Milano Malpensa Airport (MXP)	18,714,187	19,087,098	15,046,206	80%	15,193,330	80%	3,667,980	20%	3,893,767	20%	X	-	-	-	X	-	40.0	5,20	7,400	10.430	X
	Helsinki Airport (HEL)	16,462,598	19,088,239	11,992,291	73%	11,599,934	61%	4,470,307	27%	5,468,497	29%	X	-	-	-	-	-	19.0	1,36	2,811	10000	X
	San Diego International Airport (SAN)	16,917,595	16,868,732	253,763	2%	253,030	2%	16,663,831	99%	16,615,701	99%	X	-	X	-	-	-	5.0	4,30	1,545	7725	X
	London Stansted Airport (STN)	18,562,000	18,044,400	11,459,549	62%	16,590,200	92%	7,102,451	38%	1,454,200	8%	X	-	-	-	X	-	48.0	8,27	5,200	26.000	X
	Gimpo International Airport (GMP)	17,565,901	18,513,927	3,460,875	20%	3,678,852	20%	14,105,026	80%	14,835,075	80%	X	-	-	X	X	-	18.0	25,60	16,000	4.000	X
	Brisbane Airport (BNE)	19,061,008	20,100,189	4,139,902	22%	4,287,681	21%	14,921,106	78%	15,812,508	79%	X	-	-	-	X	-	13.0	2,20	346	9.000	X
20 to 40	São Paulo/Guarulhos International Airport (GRU)	26,849,185	30,003,428	10,380,540	39%	11,355,594	38%	16,468,645	61%	18,647,834	62%	X	-	-	-	-	-	25.0	20,30	7,383	3.098	No
	London Gatwick Airport (LGW)	31,342,000	33,644,000	18,958,570	60%	29,923,391	89%	12,383,430	40%	3,720,609	11%	X	-	-	-	X	-	45.0	8,27	5,200	32.000	X
	Toronto Pearson International Airport (YYZ)	31,936,098	33,435,351	10,576,567	33%	11,377,732	34%	12,730,680	40%	13,078,513	39%	X	-	-	-	-	-	23.0	6,10	4,149	11.000	X
	Rome Ciampino Airport (CIA)	35,956,295	37,406,099	23,299,679	65%	24,463,588	65%	12,656,615	35%	12,942,510	35%	X	-	-	-	X	-	32.0	4,18	2,161	4.000	X
	Atatürk International Airport (IST)	32,143,819	37,452,187	20,342,986	63%	23,847,835	64%	11,800,833	37%	13,604,352	36%	X	-	x	-	-	-	24.0	13,25	6,211	7,076	X
	Miami International Airport (MIA)	35,698,025	38,314,389	16,891,956	47%	18,417,513	48%	18,806,069	53%	19,896,876	52%	X	-	-	-	X	-	13.0	5,50	4,687	8,724	X
	Munich Airport (MUC)	34,742,222	37,782,256	25,318,699	73%	27,879,045	74%	9,279,935	27%	9,755,169	26%	X	-	-	-	X	-	28.5	2,60	4,440	20.000	X
	Sydney Airport (SYD)	35,562,000	36,022,614	11,273,154	32%	11,743,372	33%	24,288,846	68%	24,279,241	67%	X	-	-	-	X	-	9.0	4,28	2,058	12.000	X
	Incheon International Airport (ICN)	33,478,925	35,062,366	32,949,518	98%	34,537,845	99%	529,407	0%	524,521	0%	X	-	-	-	X	-	48.0	25,60	16,000	11.303	X
	Copenhagen Airport (CPH)	21,501,750	22,725,517	19,051,170	89%	20,324,252	89%	2,450,580	11%	2,401,265	11%	X	-	-	X	X	-	8.0	1,95	6,300	8.600	X
over 40	Dubai International Airport (DXB)	47,180,628	50,977,960	47,180,628	100%	50,977,960	100%	0	0%	0	0%	X	-	-	X	-	-	4.0	2,10	408	6.135	X
	Paris-Charles de Gaulle Airport (CDG)	58,166,034	60,970,551	47,347,151	81%	49,447,116	81%	10,818,882	19%	11,523,434	19%	X	-	X	-	X	X	23.0	11,70	20,980	20.000	X
	John F. Kennedy International Airport (JFK)	46,514,154	47,683,529	23,109,877	50%	23,920,483	50%	23,404,277	50%	23,763,046	50%	X	-	-	X	X	-	19.0	22,21	10,400	18.000	X
	Beijing Capital International Airport (PEK)	73,948,000	78,675,000	17,229,882	23%	17,590,570	22%	56,718,230	77%	61,084,488	78%	X	-	-	X	-	X	32.0	20,69	1,200	11.882	X
	London Heathrow Airport (LHR)	65,747,173	69,391,000	60,903,278	93%	64,672,412	93%	4,843,895	7%	4,718,588	7%	X	-	-	X	X	-	25.0	8,27	5,200	21,075	X
	Hartsfield–Jackson Atlanta International Airport (ATL)	89,238,059	92,389,023	9,139,022	10%	9,856,954	11%	80,099,037	90%	82,532,069	89%	X	-	-	-	X	-	16.0	5,45	1,552	30.000	X
	Madrid-Barajas Airport (MAD)	49,866,113	49,662,512	20,636,095	41%	32,449,857	65%	29,230,018	59%	17,212,655	35%	X	-	-	X	X	-	9.0	6,50	5,390	19.796	X
	Hong Kong International Airport (HKG)	50,348,960	53,314,213	33,178,000	66%	52,749,262	99%	17,170,960	34%	564,951	1%	X	-	-	-	X	-	34.0	7,06	6,480	3.000	X
	Singapore Changi Airport (SIN)	42,038,777	46,543,845	42,038,777	100%	46,543,845	100%	0	0%	0	0%	X	-	-	-	X	-	17.0	5,31	7,315	4.750	X
	Dallas/Fort Worth International Airport (DFW)	56,905,600	57,806,917	5,460,318	10%	5,509,372	10%	51,445,282	90%	52,235,947	90%	X	-	-	-	X	-	27.0	6,64	1,358	39.800	X

PROPOSED METHOD

This section presents the procedure proposed to establish the estimated passenger traffic to an airport, by applying a mathematical model.

According to the data in Table 1 and the analyses carried out previously, plus an analysis of the graphs plotted for each criterion[1], a relation can be perceived between the passenger traffic, the population and the car parking spaces for each airport. In this analysis we combine the total number of passenger traffic for different airports that are located at the same area and their respectively car parking spaces.

We used multiple linear regression to determine a mathematical model.

Multiple linear regression:
$y_i = a + b_1X_1 + b_2X_2 + ... + b_nXn_i$
Where:
y_i = Passenger traffic
X_k = variables chosen as determinants

Mathematical model adopted:

$$y = a + b_1 \text{ (Population)} + b_2 \text{ (Car Parking spaces)}$$

where y is the Passenger traffic calculated for each airport, and a, b_1 and b_2 are coefficients, which are determined after calculating the regression using Microsoft Excel.

The Appendix contains a summary of the results obtained from the linear regression.

Analysis of the summary of the statistical results provided by Microsoft Excel leads to the following equation:
$y = 7{,}180{,}970.2 + 1.543\ X_1 + 1{,}295.5\ X_2.$

This equation is valid because it has a high value of R^2 (0,71), corresponding to 71% of the association between the dependent variable (y) and the two dependent variables, and suitable t-statistics for the variables X_1 and X_2. The t-value obtained in relation to the intercept is more than 2.

Equation defined:

$$y = 7{,}180{,}970.2 + 1.543 * \text{population} + 1{,}295.5 * \text{Car Parking spaces} \quad \text{Equation 1}$$

t = 2.1345 t = 4.247 t = 8.231

[1] We prepared pair-wise graphs between the following characteristics: total passenger traffic, domestic passenger traffic, international passenger traffic, city distance, population, demographic population and car parking spaces.

It is important to mention that more than 20 different combinations analysis between the data were made, specially using public transportation data as subway length, railway length and parking spaces. However, in any analysis the result obtained were sufficient acceptable to mention in this paper, the R^2 was always inferior than 0.5 and the t-statistics were sometimes negative and inferior than 2.

The next section presents the considerations on all the data gathered on each airports and comparisons with the others selected.

DATA ANALYSIS

Some observations are possible from analysis of the data on each airport chosen.

Considering the airports that have from 5 to 10 million passengers, only two airports are connected with tracked system. One of them is the farthest from the city. In relation to car parking, 30% of the airports present car parking below 2,000 spaces and the highest one can be justified by its predominant domestic traffic and localization, in a region of the United States with different kind of life style and high motorization index. In addition, 60% have predominantly domestic traffic and 66% of those have more than 2,000 parking spaces. Comparing the airports distance to the city reference 30% have less than 10 km distance and 66% of those have variety of parking lots. In relation to the variety of parking lots, 80% presents the variation.

Considering the airports that handle over 10 to 15 million passengers, 30% have predominantly domestic traffic and 66% of those have more than 4,000 parking spaces. In relation to parking lot 20% of the airports don't present variety of parking lots and 50% of those have less than 4,000 car parking spaces. In the public transport sector 60% of the airports are connected with tracked system considering that in the rest 40%, 75% of those airports are located in developing countries.

Considering the airports that have over 15 to 20 million passengers, 60% have predominantly domestic traffic and 66% of those have more than 6,000 parking spaces. Related to parking lot 10% don't present variety of parking lots and 100% of those have less than 6,000 car parking spaces. In relation to public transport 80% of the airports are connected with tracked system considering that in the rest 20%, 50% of those airports are located in developing countries.

In relation to the airports that handle over 20 to 40 million passengers, 30% have predominantly domestic traffic and 67% of those have more than 8,000 car parking spaces. Only 10% doesn't have different types of parking lot available and a tracked system connecting to the selected airport.

With respect to airports with more than 40 million passengers, 100% have public transportation based on tracked system. In relation to the type of traffic, 30% is domestic and 70% of the parking lots have more than 10,000 parking spaces. The airport distance from the city reference in this case doesn't affect the number of car parking spaces, the passenger traffic affect it.

Regarding the airports with over 40 million passenger movements the distance does not interfere directly with the number of car parking spaces. The greater the number of passengers processed and the number of international passengers, the greater is the public transport available and reduced the number of parking spaces available.

According to Kazda, there are several options for providing the link airport-city that should be compared. In relation to railway transport building a special line is, depending on its length, economically justified only for large airports with a minimum of 7 million passengers a year (mppa) for a spur line and normally more than 10 mppa for a dedicated link. Applying this to the study only 11% of the airport that have between 7 and 10 million passengers per year have connection with railway transport.

Considering all the airports selected those located in United States regardless to the volume of passengers presents a higher number of parking lot spaces comparing to the average.

In relation to the public transport connected to the airport, 68% have tracked system and 82% of those tracked systems are rail systems. In the selected airports 16% presents more than one tracked system to connect to the airport (subway and train or subway or high speed train or VLT, train and high speed train). We can notice that there isn't a connection to any airport by BRT.

Distant airports to the city reference present public transport connections by tracked system. For airports with more than 25 km distance 87% have tracked system (train, subway or high speed train).

Comparison of the population density and public transport to the airport shows that there is no standard for comparison.

Regarding the three airports with the highest passenger movements the traffic is predominantly domestic and 67% are in a developed country and have high number of car parking spaces and 33% is in a developing country and the number of car parking spaces is three times as lower as the other two. However the lowest one offers more different kind of public transport systems.

Comparing the top 10 airports with the highest number of car parking spaces, only one don't have yet connection with tracked system and 30% have domestic traffic predominant.

In relation to variety of car parking, considering all the airports selected 88% present variety of parking lot and the rest of the airports 100% is located in developing country in South America.

Through out the proposed method we can observe the positive relationship between total passenger traffic, population and car parking spaces.

In general Latin American regions do not follow the concept of a transportation network encompassing all systems. Instead, the systems are independent, with occasional initiatives to integrate certain bus routes with subways or commuter trains; the same occurs to connections to airports.

CONCLUSIONS

This paper just presents an overview of the public transport availability to connect the airport and the city reference. The modal split, the quality of the service, the frequency and the price are not discussed, however it is clear that this kind of factors influence the use of the public transport.

We can notice that must exist equilibrium between the airport and the public transport that connects the airport to the city. One of the aspects that contribute to the airport growth is the existence of a good public transport service and parking infrastructure and the necessity to always improve the public transport service is the continuous increase of the airport passenger movements.

Through this paper we can observe that as the airport handles more passengers the necessity to have high capacity transport system is fundamental. The rail system is the type of transport that exists in 56% of the airports selected. However as the passenger movements increases other types of track system are included as the metro and VLT systems to link the city and the airport.

Nowadays some decision makers are trying not to make big investments in the transportation area but still having to deal with the increase of the public transport demand, the BRT system is being more and more used in a lot of countries in the world. However it can only be included in the transportation network for some specific objectives and in this paper we can notice that this system is not used to connect the city to the airport.

It is clear the use of different types of car parking lots in the airports nowadays. In the selected airports, only 12% don't have variety of parking lots. The different types of parking lots exist to attend the different types of users, passengers or workers. For passengers, the different types of trips, domestic or international, the localization of the airport and the price influences the selection of the car parking. In some countries of Latin America there isn't any kind of car parking strategy but the public transport itself is not well planned and integrated.

Distant airports to the city reference present public transport connections by tracked system. In the selected airports, those with more than 25 km distance 87% have tracked system (train, subway or high speed train).

The predominant type of market served (domestic or international) interferes with planning strategy, public transport provision and number of car parking spaces.

The population and the car parking spaces influences the total number of passenger traffic in an airport or the sum of passenger traffic in more than one airport at the same area. It is important to mention that a relationship between the passenger traffic and the public transport could still exist, however with this airport selection this could not be proved. It is recommended to apply the same methodology to different or more airports to can really prove their relationship.

As Kazda mentioned when designing the airport and planning its development, the transportation to and from the airport has to be considered as an integrated system, including transportation by passenger cars, taxes, rental cars, buses, coaches and railway transport, not forgetting also the use of marine transport and helicopters where appropriate.

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APPENDIX

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,84679277
R Square	0,717058
Adjusted R Square	0,7029109
Standard Error	13978970,7
Observations	43

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1,98092E+16	9,90461E+15	50,6858643	1,08131E-11
Residual	40	7,81646E+15	1,95412E+14		
Total	42	2,76257E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	7180970,21	3364095,076	2,134591932	0,038973665	381880,5076	13980059,91	381880,5076	13980059,91
population	1,54344819	0,363393506	4,247319118	0,00012533	0,809002521	2,277893851	0,809002521	2,277893851
Parking spaces	1295,54558	157,3948244	8,231182865	3,85209E-10	977,4387786	1613,652384	977,4387786	1613,652384