PARAMETERS FOR DIMENSIONING CAR PARKING LOTS AT BRAZILIAN AIRPORTS

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Abstract

This paper aims to investigate car parking lots at Brazilian airports. In order to reach this goal, a wide range of data was colleted at Hercílio Luz airport, located in Florianópolis (state of Santa Catarina), and at Salgado Filho airport, located in Porto Alegre (state of Rio Grande do Sul). The data analyzed tackled the different types of parking lots available, the parking lot users' profile, the length of staying in a parking spot, and the parking occupation rates. For a global sample of 26 airports administered by INFRAERO (the Brazilian Airport Infrastructure Authority), a linear regression model was proposed, which provides the number of cars using the parking lot per year, per month, as well as the busiest day in relation to the corresponding number of embarking and disembarking passengers at the airport. This information allows transportation planners to estimate the number of parking stalls required at Brazilian airports when being expanded or built.

1. INTRODUCTION

Airports are important Traffic Generation Poles in urban areas, originating and attracting a great number of road trips, which brings about problems regarding traffic flow and safety in the main accesses to the airport and its surrounding areas, as well as requires a considerable number of car parking space.

In general, airports are complex systems due to the diversity of their users (passengers, airline and administration employees, visitors, attendants, etc.), the interrelation among them, and the different transportation means they may use.

As stated by Keefer (1966) and Leher & Freeman (1998), who investigated road access to airports and airport parking, it is difficult to make generalizations based on the models and parameters obtained in the studies for the complexity already mentioned, as well as the diversity of airports and realities of the cities where the airports are located.

Ashford and Wright (1984) argue that transport planners find it difficult to determine the localization and the number of car parking stalls at airports.

In Brazil, Muller et al. (1988) have recommended some figures for parking lot dimensioning: 1.5 to 2.0 stalls for every passenger at peak hours; 1.0 spot for every passenger at peak hours for employees' parking, and 0.4 to 0.8 stalls for every 1,000 passengers per year for the airport as a whole. In the United States, the FAA (Federal Aviation Administration) suggests offering 0.5 stalls for every 1,000 passengers per year.

As for traffic in the access roads, and solutions for existing traffic jams at LAX (Los Angeles International Airport), Schoenfeld (1979) pointed out two solutions: offering parking at the airport peripheral areas and encouraging the replacement of automobiles by vans, to transport people from these parking lots to the airport, and back to them.

Other studies, such as ITE (6A19, 1980 committee), Mohr and Gosling (1997), Foote et al. (1997), Shapiro (1998), and Lehre (1998), addressed circulation problems, regarding road accesses to airports, as well as ways of improving public transportation (buses, vans, trains, etc.) as an alternative to reach the airports, in an attempt to minimize traffic jams and reduce the necessity of car parking space at airports.

In Brazil, from 2000 to 2004, an extensive research on road trips to airports was carried out, focusing on case studies, concerning Hercílio Luz airport, in Florianópolis, and Salgado Filho airport, in Porto Alegre. These studies collected data regarding the demand for air travels, the characteristics of both

airports (which are administered by INFRAERO), their users' profile, obtained by means of interviews, the characteristics of road trips, the assessment of the amount of vehicles using the parking lots, as well as the quantity of parking stalls available (Goldner, 2002).

A questionnaire was also sent to the superintendent of the other airports, run by INFRAERO in Brazil, in order to collect data about their parking lots. These have provided the researchers with information about 24 airports and, together with airports of Florianópolis and of Porto Alegre, there was a total of 26 airports.

Another issue addressed by these studies referred to the choice of parking types available, applying parking charges through the Logit Model and the stated preference technique (SP). In addition to that, they have been studying choice models of road transportation means, taking into consideration the variables journey time and cost, through the Multimodal-Logit model (Goldner, 2004). The results achieved by these two studies will not be presented in this study.

Thus, the purpose of the present study is to focus on information, regarding the demand for car parking at Brazilian airports, constituting the sample mentioned above, as well as to suggest utilization rates and models for predicting the amount of vehicles, allowing adequate planning of parking stalls for the airports in the country.

For Hercílio Luz and Salgado Filho airports, the study presents the distribution of road trips for different means of transportation, the parking facilities chosen by their users, the parking lot occupation rates for a whole year (for their busiest month and day, and for their peak hours), matching the number of vehicles with the number of embarking and disembarking passengers in corresponding time periods, as well as the distribution of staying length in the parking stalls.

A second step was taken to add this information to the data, collected from the other airports, that made up the sample, thus yielding a linear regression model, relating the quantity of vehicles in the parking lot (yearly, monthly, and daily) to the number of embarking and disembarking passengers for specific time periods at the airport.

2. COMPOSITION OF THE STUDIED SAMPLE

Two airports, Hercílio Luz and Salgado Filho, were thoroughly investigated, by means of a questionnaire filled in by their administration staff, face-to-face interviews with users, and assessment of the number of vehicles utilizing airport parking areas. Both airports are

located in capital cities in the south of Brazil.

Hercílio Luz airport, located in Florianópolis (Fpolis), state of Santa Catarina, is run by INFRAERO and plays an important role both in Brazil and in MERCOSUL (Southern Common Market, including Argentina, Brazil, Paraguay, and Uruguay), mainly because the city attracts both Brazilian and Argentinean tourists.

In 1999, this airport received 891,354 passengers: 21% of international flights, 60% of domestic flights, and 19% were regional passengers. The airport has a single outdoor parking lot with 450 parking stalls. In 2004, the number of embarking and disembarking passengers was 1,382,577, 94% of domestic flight users.

Salgado Filho airport, in Porto Alegre (POA), state of Rio Grande do Sul, is also administered by INFRAERO and plays an important role in Brazil. It was ranked in the 8th position of the list of Brazilian airports, regarding domestic traffic flow, as demonstrated in the study conducted by Pereira Filho et al., 1999. In 2004, this airport ranked the 7th position of the same list.

In 1999, Salgado Filho airport received 2,337,614 passengers: 8.20% of international flights, 70% of domestic flights, and 21.80% of regional passengers. In September 2001, a new passenger terminal was inaugurated, offering two parking facilities: an outdoor parking lot with 770 stalls, and one indoor, with 1,440 parking stalls. In 2004, the number of embarking and disembarking passengers rose to 3,215,546, out of them, 91.8% were users of domestic flights.

The 66 airports composing the network administered by INFRAERO were contacted by mail to complete a standard questionnaire on the flow of passengers and vehicles in the parking facilities. Twenty-six of these airports (including Hercílio Luz and Salgado Filho airports) filled in those questionnaires. Table 1 displays the names of the airports composing the sample investigated by the present study.

Table 1 - Airports that filled in the questionnaire

#	Airport	#	Airport
1	Ilhéus Airport (BA)	14	Pinto Martins International Airport (CE)
2	Tancredo Neves International Airport (MG)	15	Petrolina Airport (PE)
3	Cariri Regional Airport (CE)	16	Macaé Airport (RJ)
4	Uberaba Airport (MG)	17	Corumbá International Airport (MS)
5	Augusto Severo International Airport (RN)	18	Imperatriz Airport (MA)
6	Belo Horizonte Airport (MG)	19	Bartolomeu Lysandro Airport (RJ)
7	Brasília International Airport (DF)	20	Hercílio Luz Airport (SC)
8	Boa Vista International Airport (RR)	21	Salgado Filho International Airport (RS)
9	Pres.Castro Pinto International Airport (PB)	22	Guararapes International Airport (PE)
10	Rio de Janeiro International Airport (RJ)	23	Congonhas International Airport (SP)
11	Cruzeiro do Sul International Airport (AC)	24	São Paulo International Airport (SP)
12	Goiânia Airport (GO)	25	Vitória Airport (ES)
13	Montes Claros Airport (MG)	26	Ponta Porã International Airport (MS)

3. MODAL CHOICE AND VEHICLE DEMANDS AT THE PARKING LOTS OF HERCÍLIO LUZ AND SALGADO FILHO AIRPORTS

For the studies previously mentioned, the following information was collected: the airport users' profile (type of user, sex, age, educational level, type of flight, purpose and frequency of air travel, occupation), the characteristics of road trips (type of means of transportation, journey duration, trip origin/destination), and the utilization of parking facilities (location, length of staying in the parking lot).

Four hundred interviews were carried out with users in each airport; at Salgado Filho airport the interviews were conducted in August and September (typical months), and at Hercílio Luz airport, they were conducted in January 2001 (peak period), due to the Brazilian summer tourism season, and in April (2001) (normal period), which is considered a typical month.

Part of the information obtained will be presented in the following paragraphs, focusing on statistics that are directly related to the study concerning parking facilities.

The percentage of users per means of transportation was obtained for both airports. Tables 2 and 3 display the results for users' entry and exit at Hercílio Luz (HL) airport, while tables 4 and 5 refer to the same items at Salgado Filho (SF) airport.

Table 2 - Distribution per means of transportation for trips arriving at HL airport

Means of transportation	Origin	Peak period		Typical period	
		Sum	%	Sum	%
Private auto	Fpolis	71	46,41	79	49,07
	Surrounding cities	24	15,69	12	7,45
Bus	Fpolis	10	6,54	14	8,70
	Surrounding cities	6	3,92	3	1,86
Shuttle	Fpolis	3	1,96	1	0,62
	Surrounding cities	4	2,61	0	0,00
Taxi cab	Fpolis/ Surrounding cities	22	14,38	39	24,22
Van	Fpolis	4	2,61	4	2,48
Others	Fpolis/ Surrounding cities	9	5,88	9	5,59
Total		153	100,00	161	100,00

During peak periods, cars were the most frequent means of transportation (62.10%), followed by taxicabs (14.38%). During typical periods, cars represented 56.52% of the total, followed by taxicabs (24.22%).

Table 3 - Distribution per means of transportation for trips leaving HL airport

Means of transportation	Origin	Peak period		Typical period	
		Sum	%	Sum	%
Private auto	Fpolis	15	46.88	12	35.29
	Surrounding cities	3	9.38	5	14.71
Bus	Fpolis	3	9.38	1	2.94
	Surrounding cities	1	3.13	0	0.00
Shuttle	Fpolis	1	3.13	0	0.00
	Surrounding cities	0	0.00	0	0.00
Taxi cab	Fpolis/ Surrounding cities	4	12.50	10	29.41
Van	Fpolis	0	0.00	3	8.82
Others	Fpolis/ Surrounding cities	5	15.63	3	8.82
Total		32	100.00	34	100.00

Regarding the means of transportations used to leave the airport, during peak periods, most users preferred cars (56.25%), followed by taxicabs (12.50%). During typical periods, private autos made 50% of the trips, and 29.41% were of taxicabs.

Table 4 - Distribution per means of transportation for trips arriving at SF airport

Means of Transportation	Origin	Driver	Passenger	Sum	%
Private auto	POA	71	64	135	46.23
	Surrounding cities	11	17	28	9.59
Bus	POA		20	20	6.85
	Surrounding cities		20	20	6.85
Taxicab	POA		75	75	25.68
Train	POA		10	10	3.42
Van	POA		3	3	1.03
	Surrounding cities		1	1	0.34
Total				292	100.00

As Table 5 shows, people predominantly arrived at SF airport by private autos (55.82%), followed by taxicabs (25.68%).

Table 5 - Distribution per means of transportation for trips leaving SF airport

Means of transportation	Origin	Driver	Passenger	Sum	%
Private auto	POA	46	54	100	64.94
	Surrounding city	4	12	16	10.39
Bus	POA		4	4	2.60
	Surrounding city		7	7	4.55
Taxicab	POA		22	22	14.29
Train	POA		3	3	1.95
Van	POA		1	1	0.65
	Surrounding city		1	1	0.65
Total				154	100.00

Most people left the SF airport in private autos (75.32%), followed by people in taxicabs (14.29%). Tables 4 and 5 show a sum larger than 400 people. It may be due to the fact that some cases considered the same person's arriving and departing trips, and most of the time, attendants were taken as users.

Considering just the users who traveled by private autos and, consequently, had to utilize some sort of parking facilities, the percentages per parking place were obtained and are displayed in Tables 6 for HL airport, and 7, for SF airport.

Table 6 - Distribution per parking place for users arriving/ leaving HL airport by private auto

Parking place	Peak period		Typical period	
	cars	%	cars	%
Airport parking facilities	81	51.92	62	37.80
Parking facilities near the airport	11	7.05	13	7.93
Curbside drop-off and pick-up areas	63	40.38	88	53.66
Others	1	0.64	1	0.61
Total	156	100.00	164	100.00

Concerning the car parking place at the airport for the flow of embarking and disembarking passengers during peak time, most users prefer the airport parking facilities (51.92%), followed by curbside drop-off and pick-up areas (40.38%). For the typical period, however, 53.66% parked at the curbside drop-off and pick-up areas, while 37.80% used the airport parking facilities.

Table 7 - Distribution per parking place for users arriving/leaving SF airport by private auto

Parking place	cars	%
Airport parking facilities	101	43.35
Parking facilities near the airport	8	3.43
Curbside drop-off and pick-up areas	124	53.22
Total	233	100.00

At SF airport, 53.22% of the people who arrived or left the airport by private autos, parked at the curbside drop-off and pick-up areas, followed by 43.35% who used the airport parking facilities.

Out of the total number of users of the parking facilities at HL airport, concerning the short-term parking (up to 4 hours), 44.44% were accompanying passengers, followed by 32.22% who were embarking or disembarking passengers. For long-term parking, 64.22% of the users were boarding or disembarking passengers, followed by 22.38% who were airport staff members. Crewmembers represented 5.24% of the users.

At SF airport, for short-term parking, 55% of the users were embarking or disembarking passengers, followed by 30.83% of people accompanying passengers. For long-term parking, 54.15% were embarking or disembarking passengers, 19.17% were airline staff members, 12.50% were airport staff members, and 10.83% were crewmembers.

For the group of people who used airport parking facilities, Tables 8 and 9 show the distribution of staying length in the parking

facilities for both HL and SF airports, respectively.

Table 8 - Distribution of approximate parking time at HL airport

Parking time	Peak period		Typical period	
	cars	%	cars	%
Up to 30 minutes	17	18.28	15	20.00
From 30 minutes to 1 hour	31	33.33	22	29.33
From 1 to 2 hours	20	21.51	21	28.00
From 2 to 4 hours	13	13.98	6	8.00
From 4 to 8 hours	7	7.53	2	2.67
From 8 to 12 hours	0	0.00	0	0.00
From 12 to 24 hours	0	0.00	0	0.00
More than 24 hours	5	5.38	9	12.00
Total	93	100.00	75	100.00

For both, peak and typical periods, the short-term parking (up to 4 hours) represented 85% of the parking facility use.

Table 9 - Distribution of approximate parking time at SF airport

Parking time	cars	%
Up to 30 minutes	28	25.69
From 30 minutes to 1 hour	31	28.44
From 1 to 2 hours	25	22.94
From 2 to 4 hours	6	5.50
From 4 to 8 hours	1	0.92
From 8 to 12 hours	3	2.75
From 12 to 24 hours	2	1.83
More than 24 hours	13	11.93

The approximate parking time at SF airport is up to 2 hours (77.06%), in which the distribution is almost uniform. Cars parking for more than 24 hours represented only 11.93% of its total amount.

The calculations of the average parking time for the sample are displayed in Tables 10 and 11. For this calculation, the average point of the interval, in Tables 8 and 9, were taken into account, and the extreme points considered then were 0.25 hours (15 minutes) and 24 hours.

Table 10 - Average parking time at HL airport

Average parking time	Peak period (hours)	Typical period (hours)
Mean for the whole sample	2.78	3.97
Mean – Short-term	1.19	1.09
Mean – Long-term	13.50	20.72

Table 11 - Average parking time at SF airport

Average parking time	Typical period (hours)
Mean for the whole sample	4.31
Mean – Short-term	0.95
Mean – Long-term	20.21

The results show that the users of parking facilities, of both HL and SF airports, behaved similarly, regarding the average parking time for the typical period, but the figures for the peak period at HL airport were rather different.

The number of cars using the parking facilities at HL airport in 1999, reached a total of 139,399. January was the busiest month, with 21,532 vehicles, representing 15.45% of the total per year. Sunday, January 10th was the busiest day of the month and of the year (1999), with 958 automobiles, representing 4.45% of its total for that month. The busiest hour of the busiest day was from 1pm to 2pm, reaching 122 cars representing 12.73% of its total for that day. This percentage is broadly denominated Peak Hour Percentage (PHP). The total number of stall in the parking lot of this airport is 450.

In this same year, 647,946 cars utilized the parking facilities of SF airport. January was its busiest month, with 62,465 cars (9.94% of its total per year). On its busiest day, in January, 2,361 automobiles (3.78% of its total for this month) were counted and this record was beaten only on a Sunday, August 1st, when travelers were returning from their winter vacations. At that time, the airport offered 750 parking stalls.

4. OCCUPATION RATES FOR THE PARKING LOTS

The data for embarking and disembarking passengers in 1999, for the busiest month and day, together with the number of cars entering to the parking facilities over these time spans, respectively, made it possible to estimate the occupation rates for the parking lots, here evaluated. The results are displayed in Table 12.

Table 12 - Calculation of the occupation rates for HL and SF airports

Parking occupation rates	HL	SF
Parked automobiles per embarking and disembarking passengers – year: 1999	0.157	0.28
Parked automobiles per embarking and disembarking passengers – January, 1999	0.156	0.29
Parked automobiles per embarking and disembarking passengers – busiest day in January, 1999	0.133	0.36
Parked automobiles per embarking and disembarking passengers – peak hour	0.177	md*

* md = missing data

The rates are expected to increase from the top to the bottom of the table, as we move from the yearly rates to the hourly rates, since the demand for parking space tends to become more concentrated, thus reaching higher values. However, this tendency is not totally confirmed for HL airport, where the rate on its busiest day is slightly lower. The expected results were obtained regarding the occupation rates at SF airport.

The comparison of the occupation rates of the two airports shows that SF airport presents higher figures, which indicate a larger concentration of cars at its parking facilities per embarking or disembarking passenger. Unfortunately, it was not possible to calculate the hourly rate for this airport, due to some missing data.

5. LINEAR REGRESSION MODEL FOR THE AIRPORTS

Taking into account the data regarding the flow of passengers and the flow of vehicles at the parking facilities of the airports, a calibration of simple linear regression models was carried out. Data were obtained through questionnaires sent by mail and filled in by 26 airports (including Hercílio Luz and Salgado Filho airports). The dependent variable (Y) was the number of automobiles at the parking facilities (yearly, monthly, daily) and the independent variable (X) was the number of embarking and disembarking passengers at the airport (yearly, monthly, daily). As described by Goldner et al (2004) at the XIII ANPET Congress, this equation is represented by $Y = \beta 1 + \beta 2\ X$.

Several modeling trials were conducted, considering the coefficients of the $\beta 1$ and $\beta 2$ regression. However, the models were not statistically reliable. Thus new modeling were conducted and adjusted considering $\beta 1=0$, i.e., the straight line crossing the origin. Furthermore, airport 23 (Congonhas International airport) was removed from the equation for being an outlying-area airport and would affect the R2 values for the

regression equations. Table 13 displays the final results for the calibration.

Table 13 - Simple linear regression models for the airports composing the sample

Type	Equation	R	R^2	N	t-test	t critical (95%)
Yearly Model	Y = 0.196 X	0.889	0.791	13	11.795	1.782
Monthly Model	Y = 0.232 X	0.885	0.783	11	12.045	1.812
Daily Model	Y = 0.255 X	0.751	0.565	8	6.227	1.895

The table above shows how models for the year 2000, and the busiest month and day, yielded good or satisfactory correlation coefficients, with t-student statistics above the critical value, for a 95% confidence interval. The β2 coefficients increased, as expected, from yearly to daily models. The only model that was not statistically reliable, and was left out of Table 13, was the one concerning the peak-hour, of which utilization is not recommended.

CONCLUSIONS

This research on airports was carried out from 2000 to 2004, and it was divided into several parts. The issues discussed in the present study are related to the investigation of car parking facilities; the data were obtained through questionnaires and interviews conducted in the year 2000, based on information concerning the year 1999, where statistics regarding the flow of passengers were reached.

The data concerning parking lots, users' profile, different types of parking facilities at the airports and surrounding areas, length of staying in the parking lot, and relevant remaining information were only collected for Hercílio Luz and Salgado Filho airports, due to their proximity and geographical location, allowing to save material and human resources. For the other 26 airports, the collected data were restricted to the number of embarking and disembarking passengers and the number of cars at the parking facilities, obtained by means of a questionnaire sent by mail.

As the capacity of airport parking facilities can be estimated through the multiplication of its daily flow of automobiles by its percentage of peak hours and then by the average staying length of parking, this study offers subsidies to transportation planners when searching appropriate dimensioning of parking stalls for Brazilian airports to be expanded or built.

In face of the difficulty in obtaining data on hourly demands for the parking lots, in order to find out the percentage of peak hours, the present study could not provide insights regarding this issue. Thus, researchers should be persistent in demanding this sort of information from the administration sector of

parking facilities at airports, since it should be easily obtained when electronically operated.

There are few studies on road trips and parking facilities at airports in Brazil. In despite of the difficulties found in collecting proper data, the present study aims to bring its contribution as well as to implement a general view on transportation field.

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