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# **The Derivation and Analysis of the Passenger Peak Hour: An Empirical Application to Brazil**

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## **Abstract**

Many different definitions are currently used to define a design 'peak' hour at airports, such that the majority of passengers receive adequate service levels and only an acceptably small proportion experience the impact of congestion. The evaluation of level of service provision depends on this definition. Previous definitions have either used a nominal hour below the absolute peak or have taken a representative hour from the schedule of flights. This paper endeavours to define this level of traffic empirically. Data for 48 Brazilian airports covering a five-year period is analysed to develop a methodology for and determine the appropriate peak hour for designed decisions. This empirically derived traffic level is regressed against annual traffic levels to establish a relationship that should enable the forecast of design peak hour demand with changing annual throughputs.

## **1 Introduction**

A variety of definitions are used to define the peak hour at airports. It is not the objective to provide facilities that result in a perfect match of unrestrained service levels for this peak as this may result in a waste of resources at other times. There is a consensus that planning should aim to satisfy demand at some level below this peak, with the result that the majority of passengers receive adequate service levels and only a small proportion experience the impact of congestion. Planning for this traffic level, for example in the design of passenger terminals, also means that the evaluation of the level of service provision will depend on this definition, so it is a crucial concept.

There have been few previous studies designed to empirically derive or confirm the appropriateness of a design peak hour definition. Matthews (1995) recently attempted to forecast levels of peak hour demand for British Airport Authority (BAA) airports by correlating them with hourly, monthly and day of the week patterns and in Brazil a number of studies have been prompted by the realisation that many airports were designed for too high a level of peak flows, thus wasting resources, and that a lack of consistency meant that service provision standards could not be consistently appreciated by the public. Initially, Andrade (1993) attempted to address this problem, but data shortcomings prevented his work reaching fruition. In this paper, an improved data-base is used and a methodology to identify the design peak hour is suggested, applied and tested.

## **2 Passenger Peak Hour Definitions**

The definition of the passenger peak hour is fundamental for a facility's design purposes. It is not sensible to use the highest hourly demand of the year for design purposes because it would result in uneconomical and wasteful investment. It is necessary to define a certain level of demand at prevailing pricing policies that the capacity of the airport can handle with an acceptable level of service, with just a few hours of operation during the year in which this passenger throughput might be surpassed.

There are many definitions of the peak hour for design purposes that are in use by airport authorities. All of them try to define an acceptable portion of the users that will receive not less than an adequate level of service during one year of operation. The main ones are described in Ashford and Wright (1992). The standard busy rate (SBR), in the past used by BAA in the UK, is the 30th highest hour of annual passenger flow, or the rate of flow that is surpassed by only 29 hours of operations at higher flows. A modification of the SBR is the busy hour rate (BHR) where the hours concept is replaced by the highest 5 percent of the annual traffic. Both methods use the same principle of ranking all the hours of the year in decreasing order of passenger flow and after that select a fraction (hours or percentage) when it is considered that some degree of congestion can be expected and tolerated.

The Federal Aviation Administration (FAA) in the US uses typical peak hour passengers (TPHP) where values are related to annual throughputs (Federal Aviation Administration, 1976). These are shown in Table 1. The busiest timetable hour (BTH), based on timetables and load factors of flights, can be used for small airports where there is little historical data available.

The peak profile hour (PPH), also used by the FAA, is the highest hourly passenger flow in the average peak day of the peak month. This measure has been used by the Brazilian Civil Aviation Authority. For many larger airports the PPH is close to the SBR. This is not the case with the Brazilian domestic airports examined here where it can range from the busiest to the 100th busiest hour because the level of demand is low on average and is subject to great variability.

Table 1: Typical Peak Hour Passengers

Total Annual Passengers	TPHP as a percentage of Annual Flows
30 million and over	0.035
20,000,000 - 29,999,999	0.040
10,000,000 - 19,999,999	0.045
1,000,000 - 9,999,999	0.050
500,000 - 999,999	0.080
100,000 - 499,999	0.130
Under 100,000	0.200

In practice, while the International Civil Aviation Organisation (1977) states that it is common practice to use the 30th or 40th busiest hour of the year, Dutch airports use the 6th busiest hour and the Aeroport de Paris uses 3 percent overload standard. In fact, the relationship between demand and capacity depends not only on the peaking characteristics

but also on the level of service to be provided at the nominal peak. The overall level of service may be adjusted according to the chosen design hour and its level of service. The essence of this choice of design hour is that it be representative of some relatively stable condition<sup>1</sup>.

### **3.Data and Methods**

#### **3.1 Data**

Airlines using Brazilian airports are required to provide throughput statistics to the Departamento de Aviação Civil (DAC). This information is gathered for regional, national and international airlines. The reliability of the level of information, however, and the ease of access differs for each sector as does the degree of currency of the information. This study uses domestic traffic data for the national airlines sector comprising, VARIG, VASP and TRANSBRASIL.

Data is available for these airlines for all 48 airports owned by Infraero which handled domestic traffic of these carriers for period 1990-1994. Information relates to daily passenger numbers by hour of embarkation/disembarkation. Some difficulties exist with the data but it is felt that the integrity of the subsequent analysis is unaffected<sup>2</sup>. From this

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<sup>1</sup> The level of service and its relation to capacity is dealt with in Mumayiz (1985) and standards are dealt with in Airports Associations Co-ordinating Council and International Air Transport Association (1990).

<sup>2</sup> The main difficulties are, first, that for 18 of the 48 airports, regional airlines have a market share of over 20 percent, so the peak hour derived from national airlines data may be irrelevant for these airports. However, in the pooled analysis, these airports are not important. Second, aggregated data from these tapes does not match official airport statistics despite the same source of information, the airlines. See Wang (1995) for full details.

data, for each airport, the 200 busiest hours were found for each year and the throughput for each of these hours and years was recorded.

### **3.1 Methods**

It has been suggested by Horonjeff and McKelvey (1994) that design peak hour traffic should be related to annual throughput. If this is the case then not only is the definition of the peak hour useful, but changes in annual throughput can allow it to be redefined using an established relationship. Simple regression analysis can be used to identify the coefficients of this relationship.

Before a regression can be estimated, however, it is necessary to define the traffic level associated with the design peak hour. The busiest hour will not be chosen because it would waste resources and because abnormal factors may result in it reaching different levels during different time periods. With such variability a useful definition of the peak cannot be obtained nor will any attempt to explain traffic in terms of annual throughput be successful. For each airport differences in the traffic levels for the 200 busiest hours covering the five years study period can be observed. The question then is, 'At what empirical level does the lack of variability in peak hour traffic allow a reasonable and useful definition of the design peak hour?' Two methods are utilised to throw light on this.

Firstly, the standard deviation for each of the 200 busiest hours is calculated for each year and divided by the mean traffic level for that hour. Plots of this for each of the 48 airports are shown in Wang (1995) and the most useful are shown in section four below. Secondly,

the coefficient of determination ( $R^2$ ) is calculated for the same 5 year traffic levels against the relevant annual throughput. This shows a stronger correlation implying the confidence with which a design peak hour can be chosen, and then successfully regressed against annual throughput in a pooled time series-cross section regression, is enhanced.

#### **4 Empirical Derivation of the Design Peak Hour**

Figure 1 plots the standard deviations for the 200 busiest hours of departing traffic for the period 1990 to 1994, for São Paulo International Airport-Guarulhos. There is, after a fluctuations at the beginning, a steady decline in this statistic until stability is reached about the 80th busiest hour. Figure 2 shows the value of  $R^2$  for the same airport where again stability is reached around the 80-100th busiest hour. Figure 3, shows the relationship between the 200 busiest hours and the cumulative percentage of departing traffic for the 5 year period and it can be seen that the definition of the design peak hour suggests a cumulative percentage of 3.5-4.5 percent of annual throughput.

Turning to Rio de Janeiro Galeão International Airport, Figures 4, 5 and 6 show respectively the standard deviation, the  $R^2$  and the cumulative traffic-busiest hour relationship. The standard deviation suggests a design peak hour as low as the 20th busiest hour, but the  $R^2$  statistic suggests a more appropriate use of the 60th busiest hour. This latter figure corresponds to 3.5 percent of annual throughput.



Figure 1: São Paulo International Airport-Guarulhos: Standard Deviation/Mean, 1990-4

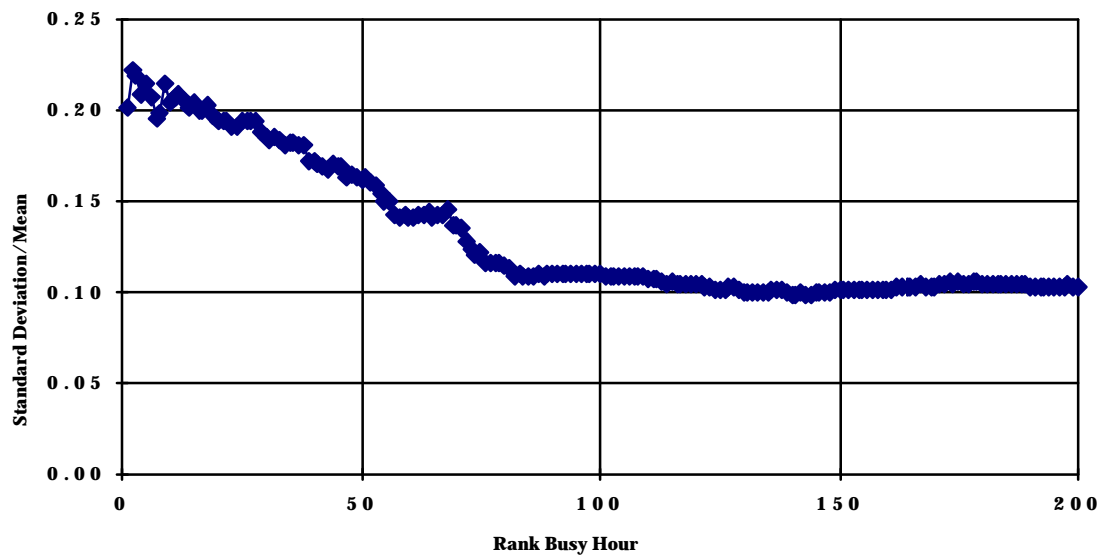


Figure 2: São Paulo International Airport-Guarulhos: Coefficient of Determination, 1990-4

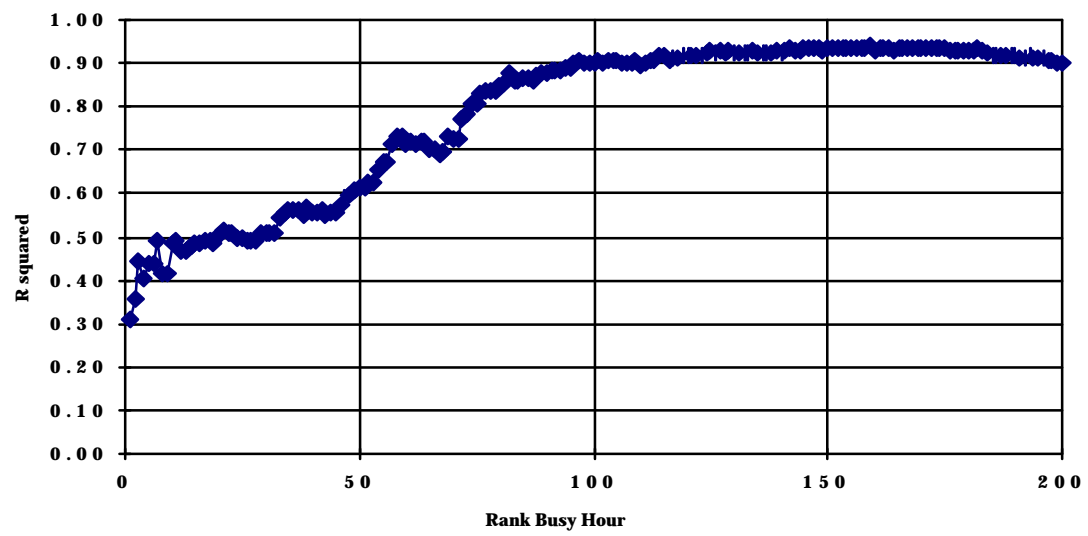


Figure 3: São Paulo International Airport-Guarulhos: Rank hour against BHR, 1990-4

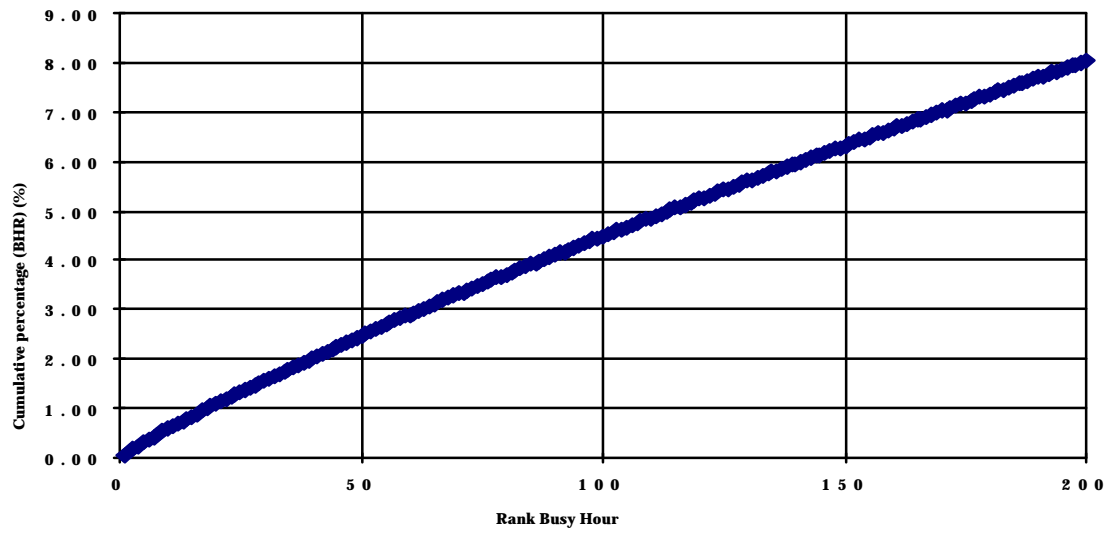


Figure 4: Rio de Janeiro Galeão International Airport: Standard Deviation/Mean, 1990-4

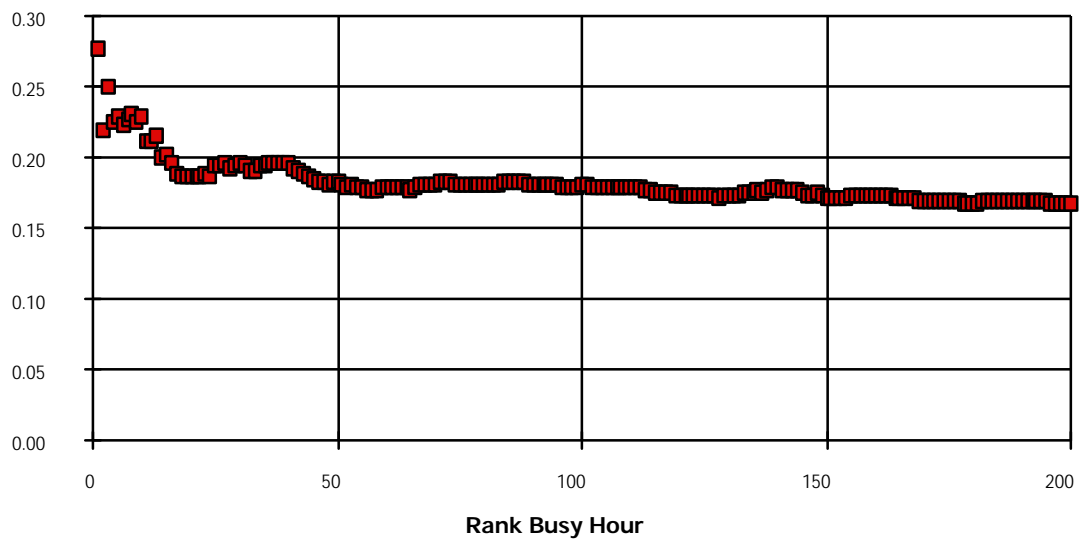


Figure 5: Rio de Janeiro Galeão International Airport: Coefficient of Determination, 1990-

4

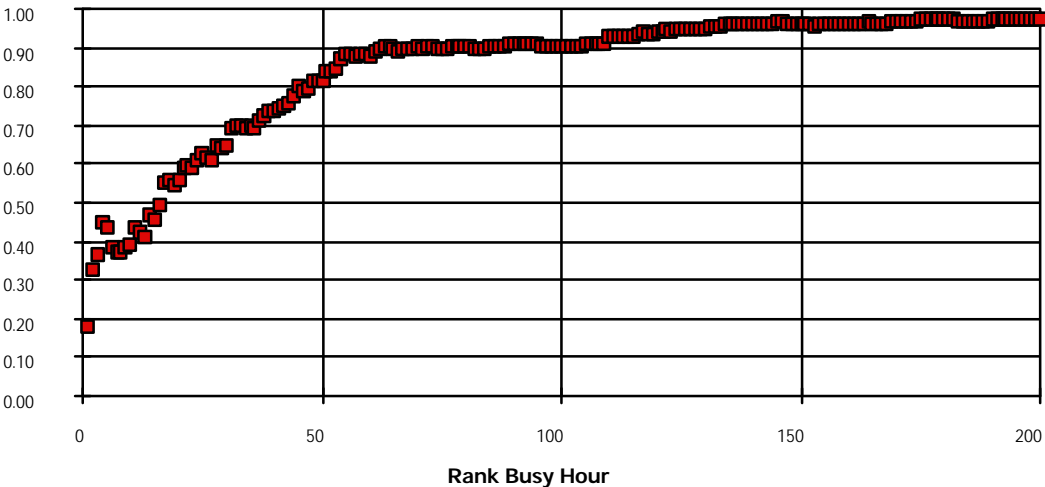
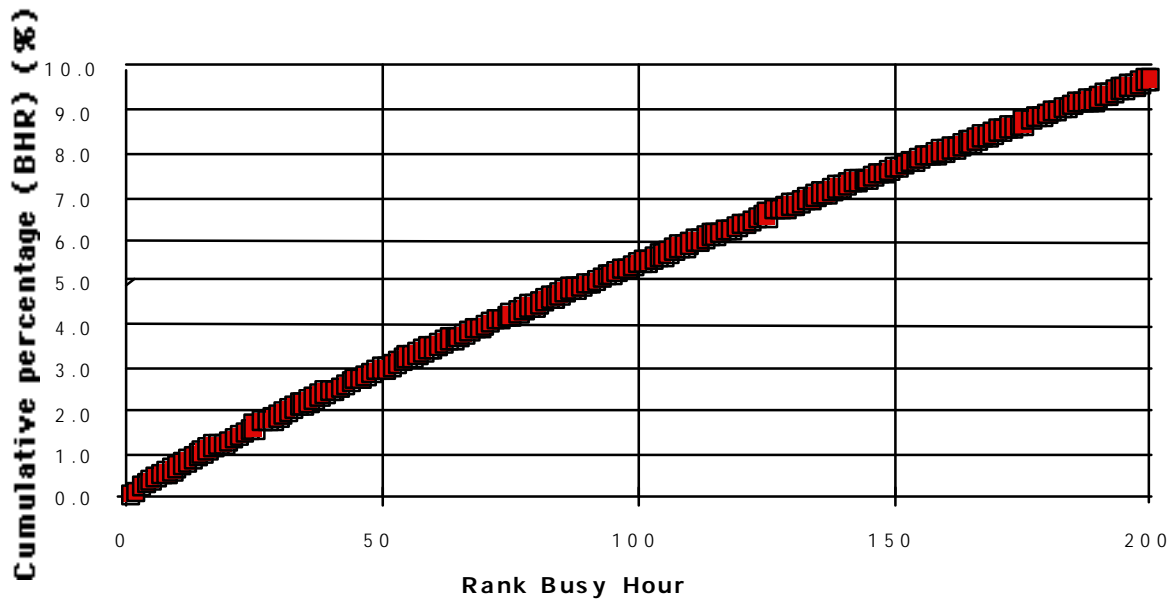


Figure 6: Rio de Janeiro Galeão International Airport: Rank hour against BHR, 1990-4



Similar graphs for the other 46 airports (Wang, 1995), all of which are smaller, do not yield such clear conclusions. Brasilia, the third largest airport, shows an  $R^2$  that rises steadily over most of the range of the busy hours, exhibiting some stability at about the 80th hour, which is equivalent to about 5 percent BHR. However, the standard deviation/mean statistic, after initial fluctuations, steadies at the 60th hour (equivalent to 4 percent BHR). The evidence for some smaller airports, in particular for SBCT, SBCY and SBGO, shows that both statistics are stable over the whole range of the busy hours rank. This is due to a lack of variability in busy hour traffic determined by a sparse yet predictable and peaked timetable with steady load factors. This lack of variability means that the methodology advocated here is not necessary for such airports in determining the design peak hour. In conclusion, it would be sensible, especially for larger airports experiencing variability in their busiest hours, to allow the BHR to vary between 3.0 and

4.5 percent, with the lower figure appropriate for larger airports and the higher percentage for smaller airports.

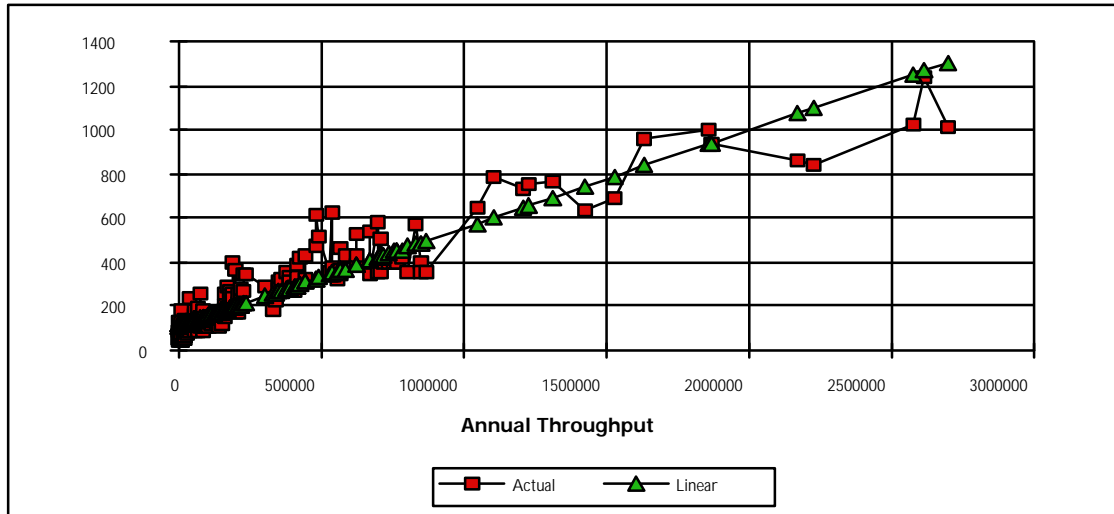
## **5 Design Peak Hour and Annual Throughput**

It can be established that regressing a design peak hour of 3.0-4.5 percent yields little difference in the resulting equations and since a figure of 3.5 percent is indicated for the main airports this is used in the remainder of this section. The pooled time series-cross uses regression involving 236 data points as three airports had no reported traffic for some of the years covered and were thus omitted. Equation 1 and Figure 7 shows the results for a simple regression of design peak hour traffic (DPT) on annual throughput for departing passengers (AT). The log of throughput (LAT) is added to the equation 2 and in Figure 8.

$$\text{DPT} = 109.18 + 0.00043 \text{ AT} \quad R^2 = 0.889 \quad (\text{Eq. 1})$$

(0.00001)

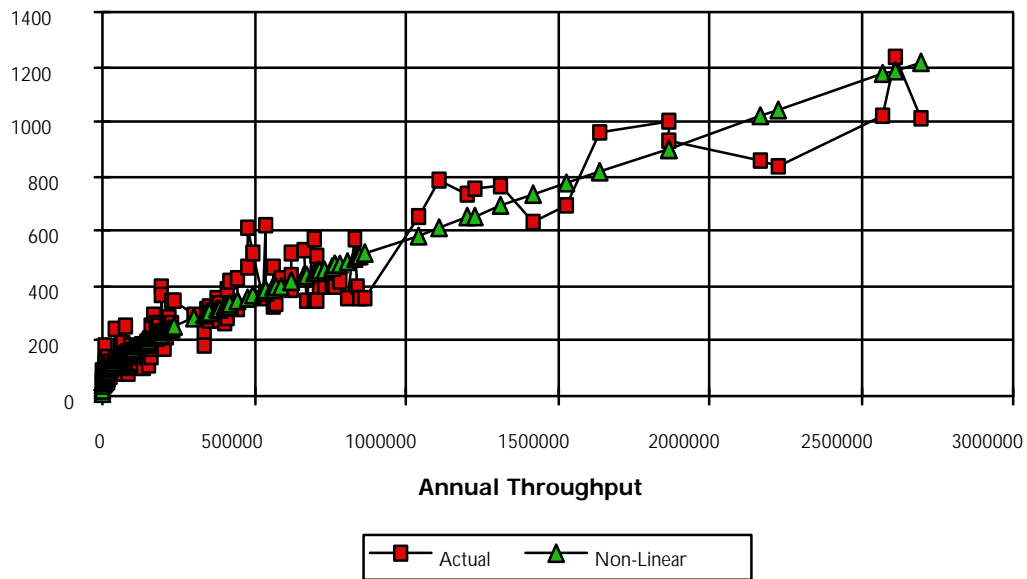
Figure 7: Regression of Design Peak Hour on Annual Departures Throughput



$$\text{DPT} = -177.40 + 0.00035 \text{ AT} + 27.301 \text{ LAT} \quad R^2 = 0.912 \quad (\text{Eq. 2})$$

(0.00001)      (3.452)

Figure 8: Regression of Design Peak Hour on Annual Departures Throughput and Log of Throughput



In both sets of results the size and sign of the coefficients are as expected and they are statistically significant. The efficiency of the model is checked by stratifying the sample of

airports to look at smaller airports and at the sample without the biggest airports. These sub-models are reported in Tables 3 and 4.

Table 2: Linear Model of Design Peak Hour for Departures

	Annual Embarkation throughput less than				All airports, with the exception of the top		
	30,000	100,000	200,000	300,000	3	2	0
constant	68.041	74.5863	73.5629	71.1110	94.58853	93.14024	109.17636
AT	0.0012	0.00081	0.00085	0.00084	0.00051	0.00052	0.00043
Standard error	0.0005	0.00010	0.00005	0.00004	0.00002	0.00001	0.00001
Rsquared	0.0709	0.35563	0.61429	0.68140	0.79425	0.84885	0.88898

Table 3: Non-Linear Model of Design Peak Hour for Departures

	Annual Embarkation throughput less than				All airports, with the exception of the top		
	30,000	100,000	200,000	300,000	3	2	0
constant	47.480	-33.076	72.0826	107.528	-132.2578	-85.36260	-177.3966
AT	0.0010	0.00039	0.00086	0.00091	0.00038	0.00043	0.00035
Standard error	0.0013	0.00025	0.00012	0.00010	0.00003	0.00002	0.00001
LAT	2.560	12.237	-0.0008	-3.92666	22.64227	17.62221	27.30676
Standard error	12.087	6.77300	0.00005	4.99018	4.18507	3.94983	3.45259
Rsquared	0.0714	0.37228	0.61601	0.68257	0.81860	0.86124	0.91248

With the exception of the results for the smallest airports, both models give a reasonable level of explanation, although the robustness of the simple linear model seems stronger as the slope coefficient appears reasonably stable. Table 4 shows the simple linear model of the design peak hour for arriving passengers. Although smaller airports are again not well explained, the level of explanation for airports with throughputs of 200,000 per annum or more are reasonable. It is noteworthy, that the slope coefficient seems to be different for



the sample including the largest airports and excluding the largest two or three from the medium sized airports.

Table 4: Linear Model of Design Peak Hour based on Arrivals

	Annual Disembarkation throughput less than				All airports, with the exception of the top		
	30,000	100,000	200,000	300,000	3	2	0
constant	61.574	76.8545	78.1074	76.53761	99.20992	100.83114	107.42097
AT	0.0023	0.00090	0.00078	0.00082	0.00049	0.00048	0.00044
Standard error	0.0009	0.00013	0.00006	0.00005	0.00002	0.00001	0.00001
Rsquared	0.0891	0.28530	0.52807	0.61464	0.77882	0.82214	0.89854

Finally, Table 5 reports the application of the same simple model to total traffic. Again, explanation is poor for smaller airports and there are marked differences in the slope coefficient for larger airports.

Table 5: Linear Model of Design Peak Hour based on Total Traffic

	Total Annual throughput less than				All airports, with the exception of the top		
	60,000	250,000	500,000	1,000,000	3	2	0
constant	85.012	99.7895	89.0319	101.29078	116.53089	117.58792	128.48231
AT	0.0010	0.00044	0.00059	0.00046	0.00037	0.00037	0.00034
Standard error	0.0004	0.00005	0.00003	0.00001	0.00001	0.00001	0.00001
Rsquared	0.0869	0.40507	0.75779	0.83578	0.88468	0.91191	0.94078

## 6 Conclusions

This paper has adopted an empirical approach to the determination of the design peak hour at airports. Using data on departing domestic traffic for 48 airports in Brazil shows that the busiest hours have different traffic levels for the five years studied. Consequently, it seems to make little sense to attempt to design for such peaks but rather to identify a busy hour that has more predictable traffic levels. Statistics have been used to determine this design peak hour in terms of the Busy Hour Rate (BHR). The evidence for the larger airports indicates that this is between 3.5 and 4.5 percent with percentages at the top of the range being more appropriate for smaller airports.

This conclusion has been examined using a regression analysis of the chosen design peak hour on annual throughput. It is noted that design peak hours in the range suggested produce virtually identical results, so 3.5 percent is adopted as the design peak hour in the subsequent work. This shows that annual throughput gives a good explanation of the design peak hour. Disaggregating the results by airport size suggests a simple linear model is appropriate and appears to exhibit reasonable stability over a range of outputs. Examining a linear model of arriving traffic supports the design peak hour derivation but offers a poorer explanation for small airports although a better one for larger airports. These results are mirrored when the methodology is applied to total traffic.

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