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The Opening Address at the ATRS 2003 Conference, Toulouse, France
By
Professor Tae Hoon Oum,
President, Air Transport Research Society, and
UPS Foundation Chair in Transport and Logistics,
University of British Columbia, Canada
July 11, 2003

Distinguished guests, ladies and gentlemen! It gives me a great pleasure to welcome all of you to the ATRS World Conference being hosted jointly by Groupe ESC (Toulouse Business School) and the ENAC (Ecole Nationale de Aviation Civile).

Today and tomorrow, in addition to the Opening and the Closing Plenary sessions, 112 papers will be presented on virtually all aspects of air transport and related topics.

2003 is a particularly challenging year to air transport policy makers, aviation executives and researchers as most of the major network airlines are experiencing unprecedented level of financial difficulties in the 100-year history of aviation. But I am reminded of Mr. Georges Clemencau, the French Leader during the first World War. He said "our country advances ONLY through crisis and in tragedy". Likewise, I am confident to predict that air transport industry will also advance through these crises. Airlines are succeeding in restructuring their service networks, and streamlining their operations to an unprecedented level, and start to listen to what their customers and markets are telling them more closely. Most major network carriers in the United States and Canada have achieved a unit cost reduction of about 25% via their recent restructuring efforts. They will be coming out of these crises with resounding success in order to serve the rising demands for efficient and cost effective services. Now, I believe it is turn for the airports and air traffic control systems to do a restructuring comparable to what airlines have been doing in recent years. In this regard, I am particularly happy to see many papers and presentations in this conference are focusing the airports and air traffic control systems.

As a final note, on behalf of the ATRS, I would like to express sincere appreciation to Mr. Herve Passeron, Director of Groupe ESC-Toulouse, and Mr. Gérard Rozenknop, Director of the ENAC, and above all, Professor Sveinn Gudmundsson for their tremendous efforts to organize this conference so successfully. I also like to express our appreciation to AirBus Industries, City of Toulouse, Toulouse Chamber of Commerce, Aeroport Toulouse-Blagnac, and EQUIS for their active participation in this program and for their financial supports.

I look forward to a stimulating conference in the next couple of days.
Thank you very much.

The Air Transport Research Society (ATRS)
World Conference
July 10-12, 2003 Toulouse, France

THE CONFERENCE

The ATRS held its World Conference in Toulouse, France, in July 2003.

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Consumer expectations of capacity constraints and their effect on the demand for multi-class air-travel

Bryn D. Battersby[*]

Abstract

This paper argues that a consumer's decision on ticket class takes into account the expected likelihood of obtaining a seat in a particular class which, in turn, partially depends on an optimum "transaction cost". Taking into account the preferences of the consumer and the information that the consumer is endowed with, the consumer will select a ticket that includes its own optimal transaction cost. This motivates the inclusion of the capacity constraint as a proxy independent variable for these consumer expectations. This then forms the basis of a model of air-travel demand with specific reference to Australia. A censored likelihood function allowing for correlation in the disturbance term across k classes is introduced. The correlation in the disturbances arises as a result of the interdependence of the capacity constraints in k different ticket classes on each flight.

Introduction

This paper advances the research that was presented at the Air Transport Research Society Conference in Seattle in 2002. The purpose, here, is to present empirical findings for demand on one particular route in the State of New South Wales, Australia, that utilizes capacity both in terms of an indicator of the expected probability of availability for a particular ticket and as an upper bound in the econometric estimation of demand for the route.

This paper's core objective is to estimate demand for seven different ticket classes on one regional route in Australia. The data is captured over one year where all seat sales on each flight for one of the airlines on the route have been made available. Further, the capacity constraint for each class is derivable through the setting that the airline uses for the class. Complexity enters the problem through the interaction of the demands for each of the ticket classes. That is, it should be expected that there will be a correlation between the demands for each of the ticket classes on individual flights. The interaction of the capacity constraints for each of the different ticket classes adds a further dimension of intricacy.

There has been a significant body of research on air-travel demand, particularly as a component of yield management research. The analyses traditionally have focused on aggregate data which does not allow a sufficiently robust analysis of different consumer types – an integral factor in the price discrimination practiced by the airlines. This paper seeks to take another step towards a deeper understanding of consumers and their responses in the air-travel market. While individual consumer data is not available, the availability of data on individual flights has encouraged the exploration of alternative estimation procedures and allowed the extraction of a number of interesting results.

The econometric models that are analysed are broken down into two categories. In the first category, the entire data set is estimated together to gather outcomes that otherwise would not be attainable because of unmoving data values – for instance, price in each of

the classes does not change over the course of the year and the only way to gather a useful price effect is to estimate an overall model of demand at the flight level. The second category of models examines demand at the class level. At this level, variation is only high in the variables of sales and capacity. Nonetheless, value can be found, particularly through a model that estimates demand for each class as part of a demand system. In this paper, a quasi-maximum bivariate Tobit system is also used so that correlations between the classes can be evaluated. This evaluation of the correlations should also allow for more efficient parameter estimates of the variables in the model.

This paper is divided into a number of sections. The next section reviews some of the recent work done in this area – particularly focussing on the role of the capacity constraint and transaction cost in the consumer's utility function. The third section reviews the econometric approaches that are used in the creation and analysis of the demand models with the fourth section briefly outlining the data and manipulation required prior to estimation. The fifth section presents the results from this initial work and the sixth section focusses on some directions for further work in this area.

The air-travel consumer, the capacity constraint and the transaction cost.

In 2002, a model of consumer choice was presented at both the Air Transport Research Conference in Seattle and at the Australian Conference of Economists in Adelaide (see Battersby, 2002a and 2002b). This model noted that consumers are now becoming more capable in their understanding of the pricing methods used by the airlines and this provided for the interaction of an expectation on capacity. This section briefly summarises those ideas as a basis for the empirical outcomes that are discussed in this paper.

As consumers become more aware of the methods used by airlines to discriminate between them, their ability to form expectations on the availability of different types of tickets improves. If we let π represent the expected probability of seat availability in

ticket class i for consumer n, and ζ represent the expected capacity or number of seats in that ticket class, then we can form a simple equation that relates the two:

$$\pi_{in} = f(\zeta_{in}, \tau_{in}, d_{in})$$
Equation 1

In this model, two other variables are included that also help to explain the expected probability of seat availability for the consumer. They are the expected demand for those seats by other consumers in the market, d, and the expected transaction cost involved in procuring a ticket in that ticket class, τ.

This last component deserves some further explanation. The transaction cost is effectively a method for the consumer to manipulate their expected probability of availability for a particular ticket class. In a comparative statics analysis, it would be expected that the higher the transaction cost, the higher is the probability of availability. Indeed, the transaction cost concept is similar to the concept of manipulability by consumers in rationing schemes (see Benassy, 1993). By entering the queue for a ticket earlier, paying in advance for the ticket, or by having someone else organise the ticketing for them, the consumer spends resources in the attempt to maximise the probability of acquiring a particular seat.

The consumer will not, however, endlessly spend on these transaction costs. It turns out that the consumer will have an optimal transaction cost for each of the available choices If we define the consumer choice problem as a random utility model, the basic model would suggest that the consumer, n, will most likely be observed to choose the alternative i from the choice set C that has the highest of the random utilities, U:

$$P(i \mid C_n) = \Pr\left[U(x_{in}, m - p_{in}, \varepsilon_{in}) = \max_{j=1..k} U(x_{jn}, m - p_{jn}, \varepsilon_{jn}) \right], \quad \forall j \in C_n$$
Equation 2

Where x is the vector of the various attributes of the ticket and characteristics of the consumer, m is the budget constraint, p is the price of the ticket and ε is the randomness associated with the observation of the choice probabilities.

If we incorporate the concept of the expected probability of ticket availability, the consumer will make a choice under a modified framework:

$$P(i\,|\,C_n) = \Pr\!\left[\pi_{in}U(x_{in}, m - p_{in} - \tau_{in}, \varepsilon_{in}) = \max_{j=1..k}\pi_{jn}U(x_{jn}, m - p_{jn} - \tau_{jn}, \varepsilon_{jn})\right], \quad \forall j \in C_n \qquad \text{Equation 3}$$

Using this approach, it can be seen that the choice that the consumer makes depends on the product of the expected probability of ticket availability and the expected utility of the ticket. Moreover, it can also be seen that the expected utility of the ticket incorporates the expected transaction cost for that ticket.

Because the transaction cost has a negative effect on the utility function while positively affecting the expected probability of ticket availability, the consumer will not try to maximise the expected probability of ticket availability. Rather, the consumer will endeavour to optimise the transaction cost such that the expected probability of availability and the expected utility combined produce the highest result. Their optimal transaction cost for a particular ticket, then, will be that transaction cost where the negative change in utility from an increase in the transaction cost is equal to the positive change in expected probability of ticket availability.

The question then arises as to how this affects the way demand is observed in the market. Clearly, if consumers are factoring in the transaction cost in their choices, then an empirical model of demand should somehow take account if this. Equation 1 highlights the interactivity of the transaction cost with the expected probability of availability and consequently the expected capacity constraint and the expected level of demand. Before proceeding it is worthwhile to note the implications of the information endowment of the consumer in their decision making process.

It is fair to assume that, up until recently, consumed were relatively naïve in their understanding of the pricing and capacity policies of the airlines. This naïvety has two clear impacts on the model presented. First, the consumer may not have full information on the available choice set and secondly, the consumer may have little information on the effect of their transaction cost on the expected probability of fulfilment. While this paper does not detail the interaction of information availability[1], it can be assumed that as the information endowment of the consumer increases, so too does the available choice set and their understanding of the interaction of the transaction cost with the expected probability of availability.

In terms of empirically examining this and noting that the expected transaction cost can be considered a partial function of the expected capacity for a particular ticket, a useful solution becomes evident. Hence, it should be expected that the consumer has become more responsive to the actual capacity constraint over time as their information endowment has improved. But the methodology of examining this is not straightforward, capacity imposes an upper limit in the econometric model as well as being explanatory of demand and the demand for any particular ticket class is understandably correlated with the demand for the other ticket classes. As such, the rest of this paper is dedicated to providing a workable approach to empirically examining outcomes based on this approach to understanding consumer choices in the air-travel market.

Establishing empirical outcomes in the face of consumer expectations on the capacity constraints

This research focuses on a number of approaches that are useful when sales and capacity data are available at the ticket level for one firm and all other data is sourced from standard areas. If more disaggregated data were available, the techniques associated with the random utility model such as the multinomial logit would serve quite well. Here, however, the approach recognises the lack of individual consumer data and instead

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[1] The presentation of the research that examines the interaction of the information endowment of the consumer in relation to the expected probability of fulfilment and the transaction cost is forthcoming.

provides a number of alternative options. In this analysis, we presuppose that there are seven ticket classes with unique capacity constraints, which are tied to various ticketing restrictions.

There are two broad approaches that can be taken, and, from within those, there are at least two techniques that can be applied to examine the data. The first approach is to estimate a model across pooled data and the second approach entails establishing demand equations for each of the classes. Both approaches have their strengths and weaknesses. The first enables an inspection of the interaction of price in the demand for air-travel on the route under inspection and also allows a comparison of the restrictions and their effect on demand. This approach also allows a general analysis of the interaction of the capacity constraint on overall air-travel demand.

The second approach involves the creation of individual demand functions for each of the classes. While there is no price variability in these classes (therefore making the price effect impossible to deduce), there is regular variability in the capacity of the classes. It is possible, using this approach, to examine the sensitivity of demand for tickets in a particular class to the capacity constraint and therefore deduce some outcomes relating to the transaction cost involved in purchasing tickets for that particular class. Moreover, recognising that in any one flight, it is highly likely that the demand equations for each of the seven ticket classes will be correlated, it is possible to create a system of equations that accounts for this correlation.

In this paper, findings of the censored approach are developed using a tobit specification. In this case, a straightforward tobit model application with upper censoring is used on the pooled data where d_i is the demand for the observation on class i, x is a vector of the attributes of the ticket and the characteristics of the consumer, ζ is the capacity constraint, k is the number of classes and u is a residual:

$$d_i = \beta_1' x_i + \beta_2 \zeta_i + \beta_3 \frac{\sum_{\forall j \neq i} \zeta_j}{k-1} + u_i \; \forall j \neq i \; \text{if} \; d_i < \zeta_i$$

Equation 4

$d_i = \zeta_i$ otherwise.

Such that the likelihood function is:

$$L = \prod_{d_i < \zeta_i} f(d_i) \prod_{d_i = \zeta_i} \int_{\zeta}^{\infty} f(d_i) dd_i$$

Equation 5

Where $f(d_i)$ is the density function for d_i. If we assume the standard Tobit with normal distributions (Φ representing the normal distribution function), the log-likelihood is:

$$\ln L = \sum_{d_i < \zeta_i} -\frac{1}{2} \left[\ln(2\pi) + \ln \sigma^2 + \frac{\left(y_i - \beta_1' x_i - \beta_2 \zeta_i - \beta_3 \frac{\sum_{\forall j \neq i} \zeta_j}{k-1} \right)^2}{\sigma^2} \right]$$

Equation 6

$$+ \sum_{d_i = \zeta_i} \left[1 - \Phi \left(\frac{\zeta_i - \beta_1 x_i - \beta_2 \zeta_i - \beta_3 \frac{\sum_{\forall j \neq i} \zeta_j}{k-1}}{\sigma} \right) \right]$$

An alternative way to examine the problem is, as mentioned, by individual classes. In this case, estimation is required for k likelihood functions similar to those in equation 8 but for individual classes only. The key difference is that the data is partitioned into each individual class which creates the undesirable characteristic of invariability across many of the independent variables. Nevertheless, there is significant variability in the capacities of the classes and this does allow for the development of some useful results.

The system of independent classes would then be:

$$d_{it} = \beta_1 x_{it} + \beta_2 \zeta_{it} + \beta_3 \zeta_{jt} + u_{it} \quad \forall j \neq i \text{ if } d_{it} < \zeta_{it}$$

$$d_{it} = \zeta_{it} \text{ otherwise}$$

Equation 7

for class $i \in C_n$ at observation t. Here, β_3 represents a vector of coefficients conformable to the vector of class capacities, ζ_j. The system of likelihood functions would therefore be:

$$L_1 = \prod_{d_{1t} < \zeta_{1t}} f(d_{it}) \prod_{d_{1t} = \zeta_{1t}} \int_{\zeta}^{\infty} f(d_{1t}) dd_{1t}, \forall j \neq i$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \vdots$$

$$L_k = \prod_{d_{kt} < \zeta_{kt}} f(d_{it}) \prod_{d_{kt} = \zeta_{kt}} \int_{\zeta}^{\infty} f(d_{kt}) dd_{kt}, \forall j \neq i$$

Equation 8

The log-likelihood for each of the equations in the system is as equation 9.

The probability becomes apparent, however, that each of these likelihood functions is correlated because the total demand for seats on a particular flight is the sum of the demands for each of the individual classes and those individual demands are partially explained by a class capacity constraint which is, itself, constrained by a total capacity constraint. That is, each of the capacity constraints sum to the total aircraft capacity[2]. To account for these expected correlations, the system of equations may be estimated somewhat differently.

The approach that is used here parallels that used by Yen and Lin (2002) which examines approaches to overcome the numerical difficulties inherent with multiple probability integrals that arise in this type of censored problem. The approach that Yen and Lin

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[2] In fact, the sum of the capacities may actually exceed the capacity constraint of the aircraft if the settings used by the airline creates that effect. Nonetheless, the interrelated nature of the capacity constraints continues to produce correlative pressure across the individual demand functions.

suggest follows the quasi-maximum likelihood method that has been used in multivariate probit estimations. In this case, however, the quasi-likelihood function is used in a tobit estimation so that the cross-equation error correlations are taken into account, therefore improving the efficiency of the model.

Following Yen and Lin (2002), the quasi-likelihood function is therefore specified as:

$$L = \prod_{i=2}^{k} \prod_{j=1}^{i-1} L_{ij}$$ Equation 9

Where L_{ij} is the bivariate tobit likelihood for d_i and d_j specified as:

$$
\begin{aligned}
L_{ij} = & \prod_{d_i=\zeta_i, d_j=\zeta_j} \int_{\zeta_i}^{\infty} \int_{\zeta_j}^{\infty} g(d_i, d_j) dd_j dd_i \\
& \times \prod_{d_i<\zeta_i, d_j=\zeta_j} f(d_i) \cdot \int_{\zeta_j}^{\infty} f(d_j) dd_j \\
& \times \prod_{d_i=\zeta_i, d_j<\zeta_j} f(d_j) \cdot \int_{\zeta_i}^{\infty} f(d_i) dd_i \\
& \times \prod_{d_i<\zeta_i, d_j<\zeta_j} f(d_j) \cdot f(d_i)
\end{aligned}
$$ Equation 10

Yen and Lin (2002) find that this approach is useful as an alternative to full information maximum likelihood (FIML) in the case where there are three alternatives. In the case under investigation in this paper there are seven alternatives and the derivation of a full information maximum likelihood result is not possible because of the intractability of the equation. Yen and Lin (2002) also suggest the use of simulator methods for the calculation of higher dimension FIMLs.

In this paper, the quasi-maximum likelihood estimation is carried using the Broyden-Fletcher-Goldfarb-Shanno descent algorithm. The standard errors for the parameter estimates are calculated using White's (1982) covariance matrix.

Data and Market Background

The route under analysis in this research is the Wagga Wagga to Sydney one-way regional route in New South Wales, Australia. Wagga Wagga is located on the Sturt Highway, which connects Sydney and Adelaide, and on the Murrumbidgee River. It is also located on the train line that connects Sydney and Melbourne. The city is also regarded as the gateway to the Riverina, one of the richest agricultural areas in New South Wales.

Sydney, the other city in the pair under examination in this study, is the largest city in Australia and is the capital of New South Wales. Sydney is internationally known as one of the key cities in Australia and is also recognised as the international gateway to Australia. While Sydney has a number of airports, Sydney Kingsford Smith International airport is the only one that offers services by the primary airlines.

Usefully, at the beginning of this research project, Kendell Airlines provided a series of data for the 1997 financial year which contained a record of sales for each class on each flight of the year. The respective settings for the classes were also provided from which capacity constraint information could be developed. The method outlined in Battersby (2002a) for the calculation of the capacity constraint for individual classes based on settings data is used in this paper.

Kendell Airlines also provided information on the prices for each of the classes. No variability in the prices was recorded over the financial year. This has a key implication for the single class models as it becomes impossible to determine a useful price elasticity. Nevertheless, in the pooled data analysis, the variability across classes provides some feedback on broad response to price. Income data is the average weekly employee earnings in New South Wales.

A dummy variable is used to identify whether there is a significant event on in Wagga Wagga on the day of the flight. Events such as major race meetings, commercial events

and government events were recorded from the regional newspaper, the Daily Advertiser. A level of arbitrariness was used in defining which events were appropriate. Other dummy variables are also included for Monday and Friday flights, weekend flights, public holidays, and school holidays.

In the pooled data, further dummy variables were used to control for the various restrictions on the each of the ticket classes. These dummy variables included the requirements to book 21 days, 14 days and 7 days in advance, non-refundable ticket type, availability only to senior citizens, and the transferability of ticket restrictions (seasonal or completely flexible).

A summary of the pooled data is presented in Table 1 while Table 2 presents a summary for data at the individual class level. It should be also pointed out that sales equals the capacity constraint in 3280 (32.17%) of the observations. In the individual class data, the following ticketing class regime exists:

Class 1 Fully flexible airfare. Highest priced.
Class 2
Class 3
Class 4 $\updownarrow$
Class 5
Class 6
Class 7 Restrictive Airfare. Lowest priced. 21
            day advance requirement. Not refundable.

Table One
Summary of Pooled Data

	Mean	Std. Dev	Minimum	Maximum
Sales (SALES)	3.394	4.630	0	34
Capacity (CAP)	10.983	7.919	0	34
Ticket Price (PRICE)	139.578	29.693	93	186
Weekend (WEEKEND)	0.286	0.452	0	1
Monday or Friday (MONFRI)	0.286	0.452	0	1
21 days advance purchase (21DAY)	0.143	0.350	0	1
14 days advance purchase (14DAY)	0.143	0.350	0	1
7 days advance purchase (7DAY)	0.143	0.350	0	1
Not refundable (NOREFUND)	0.714	0.452	0	1
Available to senior citizens (SNRCIT)	0.143	0.350	0	1
Completely flexible (FLEX)	0.143	0.350	0	1
Flexibility restricted to season (SEASFLEX)	0.143	0.350	0	1
Average Weekly Earnings (AVEARN)	573.133	4.102	568.5	580
Major Event in Wagga (WGAEVENT)	0.041	0.199	0	1
Public Holiday (PUBHOL)	0.036	0.185	0	1
School Holidays (SCHHOL)	0.231	0.421	0	1
NUMBER OF OBSERVATIONS	**10193**			

Table Two
Summary of Individual Class Data

	Mean	Std. Dev	Minimum	Maximum
Sales Class One (SALES1)	9.7445	6.6561	0	34
Sales Class Two (SALES2)	1.4629	1.8803	0	22
Sales Class Three (SALES3)	1.0137	1.4549	0	21
Sales Class Four (SALES4)	0.9464	1.2869	0	16
Sales Class Five (SALES5)	1.4478	2.123	0	20
Sales Class Six (SALES6)	4.4732	3.7867	0	21
Sales Class Seven (SALES7)	4.7685	4.1056	0	26
Capacity Class One (CAP1)	19.886	5.8956	0	34
Capacity Class Two (CAP2)	4.3764	4.5992	0	24
Capacity Class Three (CAP3)	3.5	4.346	0	23
Capacity Class Four (CAP4)	13.0934	5.8536	0	25
Capacity Class Five (CAP5)	13.6078	5.6103	0	25
Capacity Class Six (CAP6)	16.6236	4.8485	5	24
Capacity Class Seven (CAP7)	5.5357	4.5408	0	26
NO. OF OBSERVATIONS / CLASS	**1456**			

Results

The results presented in this section are preliminary. At this stage, diagnostic testing on each of the models has not taken place and there remain a number of key issues surrounding the computation of the quasi-maximum likelihood model. Central to these

latter issues are a discovered "bug" in the underlying calculation of distribution functions at extreme values in the software that is used. Nonetheless, the results do provide some useful insights into the multi-class environment and are instrumental in defining the future direction of this research.

The results for the pooled data set are presented in Table 3. These results are particularly useful because they highlight the increasing cost of the restrictions – particularly the advance purchase restrictions. More importantly, however, is the effect of an increase in the capacity constraint.

Table Three
Tobit Application over Pooled Data

	SALES
ONE	14.2193*** (3.110)
PRICE	-0.1928*** (-34.786)
CAPACITY	0.4500*** (61.546)
OTHERCAPACITY	-0.9997*** (-89.463)
EARNINGS	0.0518*** (6.604)
WGAEVENT	0.0481 (0.305)
MONFRI	0.0955 (1.247)
WEEKEND	0.4297*** (5.644)
DAY21	-19.0323*** (-60.411)
DAY14	-15.9514*** (-76.754)
DAY7	-11.1109*** (-79.614)
FLEX	2.2297*** (7.340)
SEASFLEX	2.1875*** (12.049)
PUBHOLS	0.0612 (0.321)
SCHHOLS	0.0429 (0.539)

Note: Figures in brackets indicate Standard Error / Estimate. *** indicates significance at the 0.01 level. ** indicates significance at the 0.05 level. * indicates significance at the 0.10 level.

Both of the capacity variables have signs as expected suggesting that an increase in the capacity for a particular class, other things held constant, will increase the demand for

that class. The cross capacity coefficient further supports the theoretical base suggesting that an increase in the capacity in an alternative class will have a negative impact on demand for the class under analysis.

Table 4 presents findings from the univariate Tobit models. In this case, models are estimated for each of the classes in the choice set. Price is left out of the model because there is no variability throughout the year in the price of the tickets within each ticket class.

One of the clear outcomes using this approach is the differing parameters for the cross capacity constraint estimates. Indeed, the own capacity coefficient is significant for all of the seven classes. One of the other interesting outcomes is that, in some cases, there are positively signed cross-capacity coefficients. This may be a result of the correlations that exists between the demands in each of the classes, in which case controlling for this correlation may provide more efficient and understandable estimates.

The remaining variables provide their own indications on their relationship with the sales variable. There is also some use in examining these results in conjunction with those results in table 3.

At the time of writing, a significant problem had been discovered in the estimation of the multiple bivariate Tobit model using QML. This problem was not a result of the specification, but rather the result of a discovery of a "bug" in the mathematical software. This bug was related to the calculation of the log of the distribution function. Dialogue with the software developer established that:

> "After some investigation it appears that some functions are not terminating their loops as promptly as they should for extreme arguments." (Horecny, 2003)

Nonetheless, the QML multiple bivariate Tobit model was estimable using three classes and a highly constrained independent variable set. These results are presented in table 5.

Comparison results for the three individual classes using the same specification under the univariate approach are presented in table 6.

Table Four
Univariate Tobit Estimates

	SALES1	SALES2	SALES3	SALES4	SALES5	SALES6	SALES7
ONE	-104.41***	-3.3541	10.399**	25.196***	4.7288***	-5.0906***	-2.0372
	(-6.781)	(-0.522)	(2.031)	(5.6)	(2.849)	(-1.969)	(-0.263)
CAP1	0.5867***	-0.3235***	-0.2831***	-0.1497***	-0.0277***	-0.0616***	-0.5419***
	(18.230)	(-23.541)	(-25.476)	(-16.007)	(-8.009)	(-11.456)	(-19.925)
CAP2	-0.5622***	0.4646***	-0.4454***	-0.0068	0.0026	-0.0060	-0.3216***
	(-12.006)	(24.710)	(-29.917)	(-0.498)	(0.520)	(-0.767)	(-7.436)
CAP3	-0.3009***	-0.3834***	0.5459***	0.0247	-0.0149***	0.0437***	-0.1711***
	(-5.743)	(-18.829)	(34.762)	(1.629)	(-2.651)	(5.000)	(-4.075)
CAP4	-0.0786	0.1088***	0.1671***	0.1367***	-0.9253***	-0.0841***	0.4846***
	(-1.274)	(3.441)	(6.545)	(7.325)	(-134.920)	(-8.135)	(9.528)
CAP5	0.0548	0.0630*	0.0261	0.0275	0.9528***	-0.9007***	-0.0116
	(0.897)	(1.977)	(1.011)	(1.486)	(140.830)	(-86.606)	(-0.219)
CAP6	-0.3910***	-0.4343***	-0.3753***	-0.1586***	-0.0542***	0.9585***	-0.6537***
	(-8.280)	(-19.789)	(-20.691)	(-11.474)	(-10.613)	(119.931)	(-16.028)
CAP7	-0.1357***	-0.1241***	-0.1323***	-0.1327***	-0.0231***	-0.0614***	0.4518***
	(-3.714)	(-7.652)	(-10.029)	(-12.450)	(-5.850)	(-10.011)	(20.080)
EARNINGS	0.1980***	0.0307***	0.0038	-0.0350***	-0.0044	0.0142***	0.0452***
	(7.372)	(2.751)	(0.425)	(-4.465)	(-1.511)	(3.149)	(3.423)
WGAEVENT	0.8102	0.3548	0.1484	0.0076	-0.0676	-0.0963	0.0856
	(1.512)	(1.627)	(0.855)	(0.048)	(-1.168)	(-1.059)	(0.342)
MONFRI	0.2027	-0.2166**	-0.2891***	-0.0047	0.0080	0.1322***	0.7839***
	(0.794)	(-1.967)	(-3.176)	(-0.064)	(0.289)	(3.077)	(5.102)
WEEKEND	0.8820***	-0.2329**	-0.5331***	0.1161	-0.0493	0.9106***	0.9234***
	(3.035)	(-2.012)	(-5.814)	(1.370)	(-1.573)	(18.638)	(6.366)
PUBHOL	-0.6230	-0.1936	-0.2586	-0.1313	0.0492	0.0048	0.2258
	(-0.963)	(-0.582)	(-0.974)	(-0.695)	(0.703)	(0.045)	(0.628)
SCHHOL	-0.5826***	0.3950***	-0.2167	-0.1994**	0.1059***	0.0425	0.1538
	(-2.038)	(-3.381)	(-2.298)	(-2.380)	(3.421)	(0.881)	(1.151)
Likelihood	-3893.439	-1198.404	-894.053	-2226.128	-828.497	-1455.053	-290.064

Note: Figures in brackets indicate Standard Error / Estimate. *** indicates significance at the 0.01 level. ** indicates significance at the 0.05 level. * indicates significance at the 0.10 level.

Table Five
QML Estimates

	SALES1	SALES2	SALES3
ONE	-1.4800***	0.5453***	-0.0267
	(-3.675)	(3.717)	(-0.189)
CAP1	0.7708***	-0.0804***	-0.0245***
	(30.927)	(-7.348)	(-2.862)
CAP2	-0.6627***	0.6160***	-0.2690***
	(-10.670)	(13.021)	(-5.787)
CAP3	-0.5040**	-0.4795***	0.4191***
	(-8.191)	(-10.555)	(8.040)
$\rho21$	-0.3775***		
$\rho31$	-0.5188***		
$\rho32$	0.8897***		

Note: Figures in brackets indicate Standard Error / Estimate. Log-Likelihood = -9606.38. *** indiciates significance at the 0.01 level. ** indicates significance at the 0.05 level. ρij identifies the estimated correlation coefficient between i and j.

Table Six
Comparative Univariate Tobit Specification to QML Estimates

	SALES1	SALES2	SALES3
ONE	0.0605	6.3854***	5.8145***
	(0.143)	(22.435)	(23.538)
CAP1	0.7362***	-0.1526***	-0.1143***
	(33.033)	(-11.279)	(-9.533)
CAP2	-0.6463***	0.4210***	-0.4814***
	(-12.703)	(16.310)	(-22.517)
CAP3	-0.5666***	-0.6222***	0.3310***
	(-10.736)	(-24.303)	(15.607)
Log-Likelihood	-4248.875	-1289.875	-1109.613

Note: Figures in brackets indicate Standard Error / Estimate. *** indiciates significance at the 0.01 level. ** indicates significance at the 0.05 level

It is important to note that the QML estimates are from a joint estimation. The estimates for $\rho21$, $\rho31$ and $\rho32$ indicate the correlations between the three equations. There is a clear positive correlation between class one and class three while the other two combinations have a negative correlation coefficient. Unfortunately, because of the constrained size of the number of classes and variables, more detailed information is unavailable at this stage.

While this paper give some theoretical motivation for the use of the QML method in this type of estimation, the preliminary nature of the results suggest that further work is required on this modelling approach to validate its use.

Conclusion

This paper has presented three different approaches to examining consumer demand in a multi-class capacity constrained discrete choice environment. Those three approaches were based on the premise that consumers carry some expectations on the probability of having their choice fulfilled. That probability depends on the expected capacity, the expected demand and the optimal transaction cost for the particular choice.

The three approaches to examining demand in this environment were a Tobit panel approach, a series of univariate Tobit models for individual choices, and a quasi-maximum likelihood approach that corrects the univariate Tobit models for the correlations that exist between each of the individual class demands. While the results provided some insights into the usefulness of the various approaches, there remain a number of issues surrounding the computational application of the quasi-maximum likelihood method.

The direction of this research is to refine the QML method for more than three classes and many independent variables. Further, the research is currently undertaking the construction of a model that utilises a maximum simulated likelihood approach to simulate the high dimensional integrals present in the multi-class system.

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An airline-based multilevel analysis of airfare elasticity for passenger demand

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Abstract

Price elasticity of passenger demand for a specific airline is estimated. The main drivers affecting passenger demand for air transportation are identified. First, an Ordinary Least Squares regression analysis is performed. Then, a multilevel analysis-based methodology to investigate the pattern of variation of price elasticity of demand among the various routes of the airline under study is proposed. The experienced daily passenger demands on each fare-class are grouped for each considered route. 9 routes were studied for the months of February and May in years from 1999 to 2002, and two fare-classes were defined (business and economy). The analysis has revealed that the airfare elasticity of passenger demand significantly varies among the different routes of the airline.

1. INTRODUCTION

The liberalisation of the aviation sector and the continuously increasing demand for air transportation have determined a deep transformation in the air transport market, particularly characterised by the access of many new airspace users. In this context, customers of air traffic services show very different behaviours and characteristics (see, e.g., [10] and [11]). Moreover, their reactions to exogenous factors might be very different. In this framework, the careful understanding of the characteristics of the final demand for passenger air transportation plays a key role to assess and predict the behaviours of airspace users.

Passenger attitudes, and in particular price elasticity of demand for air transportation, vary essentially because they fly for different reasons; a broad distinction is generally made between business travellers and leisure travellers. Leisure travellers aim to maximise the utility derived from the air travel and from the associated holiday experiences, subject to a given budget constraint. Business travellers use air travel as an input to final production; generally, comfort and time constraints play a key role in their decisions for flights. The different marginal utility of the air travel for the two categories yields different sensibilities to factors affecting demand for it; in particular, many studies have pointed out that demand for business travel tends to be less price elastic than demand for leisure travel [3], [18], and [19].

This paper addresses the issue to determine price elasticity for passenger demand for a specific airline. Airfare elasticity of passenger demand is generally estimated with respect to a specific market (e.g., domestic, international, European, North-American) considering the aggregate demand to all the airlines operating in that market. Our study differs from this approach because it focuses on the passenger demand of a single airline.

First, an Ordinary Least Squares (OLS) regression analysis is proposed. It takes into account usual drivers affecting passenger air transportation demand. Then the different behaviours passenger demand may show on routes with different characteristics are investigated. To this end, a statistical multilevel approach is used. To the best of the authors' knowledge, no similar methods have been reported in the literature for air transportation problems. In particular, we determine fare elasticities for each route considered in the OLS sample. It turns out that their values largely vary form one route to another one, and such a variation is statistically significant.

This is a relevant result as it implies that the passenger behaviour may significantly differ for different routes of a same company. In turn, the reaction of an airline to perturbations of the values of the driver factors, and especially of prices, may be expected to sensibly vary for different routes. In particular, this means that routes on which a larger share of business customers may be expected, not only have lower elasticity, as everyone would expect, but also that such a difference can be numerically large (experienced elasticities more than double) and statistically relevant, even within a same company. Such a wide spread of elasticity values is a meaningful and not obvious result of the study.

The paper is organised as follows. A literature analysis on the methodologies to assess passenger demand elasticity and on the main drivers affecting demand for air transportation is proposed in Section 2. Section 3 describes the general model, introduces the main factors taken into account, and presents the network under study and the available data. In Section 4 the OLS model is specified, the results are shown and discussed. Section 5 introduces the multi-level model, and analyses its results. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

Literature provides many studies where determinants of air travel demand are investigated and methodologies to assess their influence are proposed. Important works in this field include, among others: Abrahams [2], Fridström and Thune-Larsen [7], Oum, Waters and Yong [19], Ghobrial and Kanafani [8], Jorge-Calderón [12], Abed, Ba-Fail and Jasimuddin [1], Brons, Pels, Nijkamp and Rietveld [3].

Abrahams [2] presents an econometric model to estimate the air travel demand for the domestic USA market. Unlike previous studies, besides geo-economical factors, demand is expressed also in terms of quality of service and intermodal competition terms. Coefficients are determined using a two-stage least squares procedure. Results suggest that demand is elastic with respect to airfares. In particular, long-haul routes demand is more price elastic than short-haul routes demand and vacation traffic demand is more price elastic than business one.

The study of Fridström and Thune-Larsen [7] presents an econometric air travel demand model for the entire conventional domestic network of Norway. In addition to population and income factors, airfares, travel time and inter-modal competition factors are taken into account and short-medium and long term demand elasticities are estimated. Demand results inelastic in

the short-medium term (estimated elasticity: −0.69) and elastic in the long term (estimated elasticity: −1.63) with respect to airfares and elastic with respect to travel time.

Oum, Waters and Yong [19] carry out a survey on the state-of-the-art of the research in the estimation of transport demand price elasticity. After a theoretical introduction of the concepts of elasticity, a survey on price elasticity of demand for various transportation modes is presented and the influence of some factors on demand is discussed. It turns out that demand for business travel is less elastic with respect to prices than demand for leisure travel and that price elasticity estimates from cross-section data generally are higher than those from time-series data.

The study of Ghobrial and Kanafani [8] presents an econometric model for the intercity air travel demand in USA. The model incorporates some quality of service measures as explanatory variables and coefficients are estimated using post-deregulation data. A distinction is made between services offered by airlines in peak and off-peak hours and a dummy variable is introduced for capacity-constrained airports. Results suggest that demand is elastic with respect to airfare (estimated elasticity: -1.2) and highly dependent on flight schedule and travel time.

Jorge-Calderón [12] presents a demand model for scheduled airline services for the entire network of international European routes in 1989. The model includes variables describing both geo-economic characteristics of the area where transportation took place and patterns of airline services. Flight data are also divided in three sub-samples by distance of the end-points. Results suggest that demand is inelastic respect to fares on shortest sectors and price elasticity increases with distance. In addition, short haul markets seem to be more sensitive to frequency of flights.

Abed, Ba-Fail and Jasimuddin [1] provide an econometric analysis of international air travel demand in Saudi Arabia. As explanatory variables they consider only macro-economic and demographic indicators and a detailed description of the steps followed for the development of the model is given. Results suggest that population size and total expenditures are the main determinants of international demand in Saudi Arabia.

Brons, Pels, Nijkamp and Rietveld [3] present a meta-analysis of the price elasticity estimates of demand for passenger air travel. After a description of determinants of demand for passenger air transport, they carry out a comparative re-evaluation of previous research on price elasticities for passenger air transport. They find an overall demand mean price elasticity of −1.146 with passengers becoming more price sensitive over time. Business passengers show lower price

sensitivity, with an average price elasticity of –0.8. Passengers are becoming more price sensitive over time.

To the best of authors' knowledge, the multilevel analysis introduced in this paper is a new methodology in the air transportation context.

3. MODEL DESCRIPTION

Demand for air transportation between two cities is assumed to be dependent on two main groups of drivers [7] [8] [12]. The first one is composed of the geo-economic variables determined by the economic activities, the population and the geographical or locational characteristics of the two cities between which the transportation takes place. The second group is composed of the service-related factors, determined by the quality and price characteristics of the air transport system connecting them.

The functional form selected for the estimating model is generally log-linear, as suggested among the others by [7], [8], and [12]. The relationship between demand for air transportation D and the explanatory variables is assumed to take the following functional form:

$$D = A \times \prod_g G_g^{\beta_g} \times \prod_s S_s^{\gamma_s} \tag{1}$$

where A is a constant, and G_g and S_s represent the geo-economic and service-related factors, respectively. Taking the logarithm on both sides, equation (1) becomes linear in the exponents of the factors. This allows the use of linear regression techniques for their assessment. The values of the parameters β_g and γ_s represent the variation rate of the demand with respect to the percentage variation of the corresponding factors, all other conditions being equal.

3.1 DEPENDENT VARIABLE

The dependent variable used in the model is the number of passengers D_{ift} travelling on route i in the fare-class f at day t. For this specification of the dependent variable, the demand considered is the sum of demands for all the flights on a given route and fare-class in a day. In this model a distinction is made between two main groups of fare classes, as it is explained in subsection 4.2. Moreover, here we aggregate both origin-destination and transfer traffic. As discussed below, dummy variables were included to explain the extra-traffic expected in hub airports, where the volume of transfer traffic is supposed higher. Finally, the model is non-

directional: no distinction is made between origin and destination city. This is justified by the set of data used, which revealed no significant difference in the passenger flows of the two directions of the route.

3.2 EXPLANATORY VARIABLES

According to the literature, population and regional Gross Domestic Product per capita have been introduced in the model as proxies for socio-economic characteristics of the passengers on the different routes. In our model we consider population of the total metropolitan area served by the airports. Population factor *POP* has been defined as the product of the populations of the two airport catchment areas. Also for GDP per capita in the two airport catchment areas, their product has been chosen as the explanatory factor *GDP*. As geographical and locational factors of the two cities, many explanatory variables have been tested in the model. According to the literature, the distance between the two airports was introduced (*DIST*). To take into account the inter-modal competition, a measure of the cost faced by the travellers in other modes of transportation has been taken into account. The direct competitor of airline services in the routes considered is the car (except in one case where the substitute of aeroplane is the ferry). The costs of alternative transportation modes have been considered in the *ALTCOS* factor.

Service-related variables were also included in the model. As explanatory of the service quality provided, daily frequency of flights (*FREQ*) and aircraft size used for each flight (*CAPA*) were inserted. A dummy variable *HUB* was introduced to identify «hubbing activity», and was set to one for routes from or to a hub airport for the considered airline. This variable was expected to have a positive effect on demand as hub airports handle a relevant part of transfer traffic. As regards pricing patterns, a variable *FARE* was included in the model. Since the dependent variable is demand for each fare-class in a given day, the corresponding fare introduced in each sample was the average airfare paid by travellers of the given fare-class.

Moreover, a dummy variable *COMP* was introduced to identify direct intra-modal competition. The dummy variable was set to 1 for airport pairs among which other airlines perform direct flights. A dummy variable *WEND* was introduced and set to 1 for flights performed on Saturdays or Sundays and a dummy variable *MAY* was introduced and set to 1 for flights performed in May (see Subsection 3.3). Finally, a control variable *YEAR* has been included in the model to capture the influence of the year of observation on the demand.
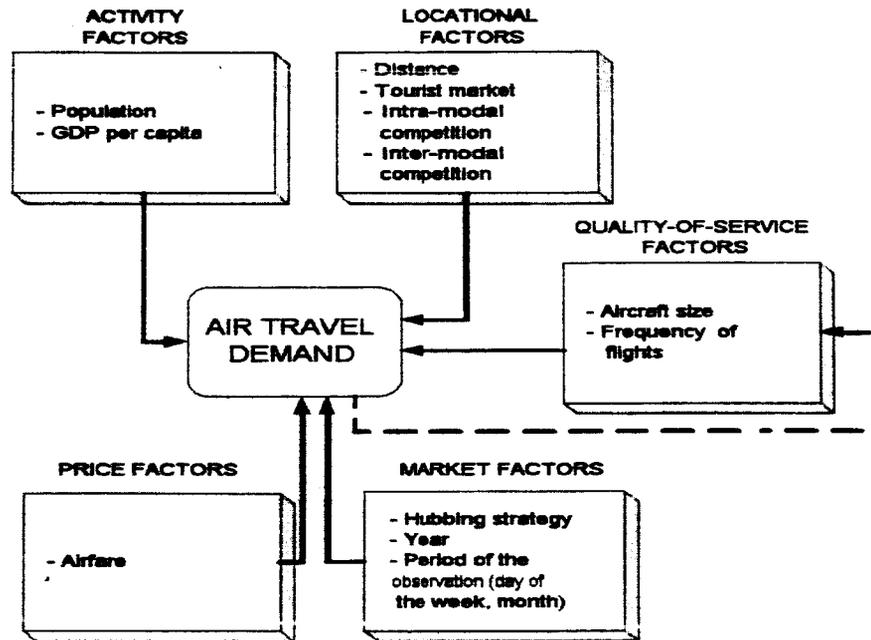
Figure 1: Drivers of air travel demand

3.3 NETWORK AND PERIOD OF TIME UNDER STUDY

Daily passenger demand for air transportation was considered using data about 9 routes of Air Dolomiti (the largest Italian regional carrier, partner of Lufthansa), for the months of February and May in years from 1999 to 2002 and from 1999 to 2001, respectively. The 9 routes used for the analysis are: Ancona-Munich, Barcelona-Torino, Barcelona-Verona, Cagliari-Genova, Paris-Verona, Frankfurt-Verona, Genova-Munich, Munich-Trieste and Munich-Venezia. These routes present different characteristics, considering Air Dolomiti network structure and market position. Some routes have, as end-point cities, one of the hubs of the airline: Munich and Frankfurt. Moreover, a group of routes is directed to a holiday resort or touristic destination. On some routes there was also a direct competition with another airline serving with a direct link the same cities. The choice to analyse passenger demand in the months of February and May has been done to capture the seasonal variation of demand, characteristic of the air travel market (to see this trends

for year 2000 in the overall European air market see [6]). February is a month of low passenger demand, while May is a month with a high level of demand; to cope with that, Air Dolomiti schedule and passenger offer is different in these two months. Moreover, the unavailability of data for the passenger demand in an electronic form has limited the analysis to data about flights performed not before 1999.

3.4 DATA SOURCES

Data of passengers flown in each fare-class, airfare paid by each passenger, aircraft used and frequency of flights have been provided by Air Dolomiti for the 9 routes. Geo-economic data (GDP per capita in the catchment area of the airports, cost of fuel) and demographic data (population in the area served by the airports) have been taken from the National Institutes of Statistics and other Statistical organisations of the countries which the respective airports belong to (see [4] for details). Distance between two cities was considered as the length of the shortest segment between pertaining airports.

3.5 AGGREGATION OF FARE CLASSES

The available data give the detail of the number of passengers for each fare-class in each flight on the routes considered in the sample. Moreover, for each passenger they give the fare paid for the flight. The data have been first aggregated by fare-class and day: the demand for each fare-class on the same origin-destination pair has been grouped through the various flights of each day. The regression analysis carried out using these aggregated data gives many unreliable coefficient estimates with an overall low explanatory power of the regression. The key factor for these bad results is that data are too much dispersed. In fact, the analysis reveals that on average there are 7-8 different fare classes per flight, a kind of "dispersion" that is mainly due to revenue management strategies of the airline, and not to substantial differences in passenger service offered. To cope with this problem, we decided to collapse all these fare-classes in only two "usual" groups: business classes and economy classes. This final aggregation is reasonable and easy to implement, since there is a clear distinction between "economic" fare-classes and "business" fare-classes. The corresponding airfare variable is the average airfare paid by passengers travelling on that class.

4. ORDINARY LEAST SQUARES MODEL

When OLS regression analysis is performed, multi-collinearity and endogeneity issues may arise. In our case, multi-collinearity analysis proved *DIST* and *ALTCOST* to be redundant factors, and therefore they have been dropped. As regards the endogeneity of factors, possible endogenous problematic variables could be frequency of flights [2] [12], airfares [8] [12] and aircraft size [12]. In our analysis we consider both airfare and aircraft size as exogenous factors affecting demand. Frequency of flights has been considered endogenous (see [4] for details).

4.1 MODEL SPECIFICATION

The estimated model is displayed in equation (2); it has been linearised taking the logarithm on both sides of the equation, as shown in (3):

$$D_{ift} = A \times POP_{it}^{\beta_1} \times GDP_{it}^{\beta_2} \times FREQ_{it}^{\beta_3} \times FARE_{ift}^{\beta_4} \times CAPA_{it}^{\beta_5} \times YEAR_t^{\beta_6} \times$$
$$\times \exp(\gamma_1 HUB_i + \gamma_2 TOUR_i + \gamma_3 COMP_{it} + \gamma_4 WEND_t + \gamma_5 MAY_t + \varepsilon) \tag{2}$$

$$\ln D_{ift} = \alpha + \beta_1 \ln POP_{it} + \beta_2 \ln GDP_{it} + \beta_3 \ln FREQ_{it} + \beta_4 \ln FARE_{ift} + \beta_5 \ln CAPA_{it} +$$
$$+ \beta_6 \ln YEAR_t + \gamma_1 HUB_i + \gamma_2 TOUR_i + \gamma_3 COMP_{it} + \gamma_4 WEND_t + \gamma_5 MAY_t + \varepsilon \tag{3}$$

where subscript i represents route, f represents fare-class ("business" or "economy") and t is a progressive index that indicates the day of the observation. Greek letters are the estimated factors. Coefficients β_n of the n quantitative variables represent the direct elasticity of demand with respect to a change in the corresponding factor, γ_m are the coefficients of the m qualitative variables, α is the constant term and ε is the error term of the estimation.

4.2 EMPIRICAL RESULTS

The results of the OLS regression analysis are presented in Table 1.

Explanatory variable	Coefficient	Estimated coefficient	t-statistic
Constant	α	-1.226	-1.680
Population (*POP*)	β_1	0.128	6.285
GDP per-capita (*GDP*)	β_2	0.127	3.342
Frequency of flights (*FREQ*)	β_3	0.862	31.884

Airfare (*FARE*)	β_4	-1.058	-71.479
Aircraft seat capacity (*CAPA*)	β_5	0.636	13.936
Year (*YEAR*)	β_6	0.070	4.164
Hub airport (*HUB*)	γ_1	0.241	3.564
Tourist market (*TOUR*)	γ_2	0.312	4.598
Direct competition (*COMP*)	γ_3	-0.088	-3.227
Weekend (*WEND*)	γ_4	-0.442	-25.566
May (*MAY*)	γ_5	0.080	5.198
Observations	6700		
R^2_{adj}	0.627		
Fisher Test	1024.59		

Table 1: Estimation results

The adjusted multiple determination coefficient R^2_{adj}, that indicates the percentage of variance in passengers demand explained by the selected drivers, is 62.7% for our model. This result, although lower than the ones found in [2] and [12], is higher than the values found in [8] and only slightly lower than the results in [7]. The *Fisher Test* value *F*, that indicates the overall significance of the estimated regression line, is 1024.59. Considering such value for the *F Test*, the *F* distribution, with 10 *(k-1)* and 6689 *(n-k)* degrees of freedom, allows the rejection of the null hypothesis, i.e., all partial slopes are simultaneously equal to zero or, alternatively, $R^2 = 0$.

The results of the regression analysis show that all the estimated coefficients are of the expected sign and all are statistically significant at the 0.05 level. In the following, the impact on the passenger demand of the main drivers is described in more detail.

4.3 ANALYSIS OF THE RESULTS

4.3.1 Price Elasticity

With regard to prices, the estimated elasticity of passenger demand for air transportation with respect to airfare is −1.058. This coefficient is associated to a very high value for the *t-test* *(|t| > 70)* that implies a very high significance of the elasticity coefficient. The literature provides a slightly higher value for the overall market; a recent meta-analysis [3] [13] indicates that studies published on this topic reveal a mean price elasticity of −1.146. Nevertheless, Air Dolomiti is an airline oriented to the business travellers, which is a segment less sensitive to changes in airfares

than the leisure travellers. In fact, studies focused on business class passengers on the past years revealed an average price elasticity of travel demand of –0.8 [3]. However, this latter figure refers to the whole business passenger market. Instead, competition reasons imply that the price elasticity of demand for a single company is generally higher than the price elasticity of demand for the whole market where it operates. Moreover, in the latter years, faced with the liberalisation of the European air market [11] and an increased choice of airlines and prices, the business travel market is becoming more and more price sensitive. Recent studies indicate an increasing tendency for business travellers to travel economic and discounted classes, as it is also proved by the fact that and airlines are developing various economic measures and marketing strategies to maintain their loyalty (frequent flyers programmes, web check-in, etc.) [14] [15].

4.3.2 Other factors

Frequency of flights on a route is found to have a positive effect on passengers demand, with an elasticity coefficient of 0.862. GDP per-capita and Population factors have a small positive effect on passenger demand. The estimated coefficient of aircraft seat capacity is 0.636. All these elasticity results are in line with the findings in [8] (see [4] for more details).

4.3.3 Dummy Variables

Dummy variables to characterise hubbing activity and holiday resort destinations have a positive coefficient that indicates the presence of a larger volume of traffic due to the role of connecting point of the hub and the attractiveness of tourist destinations respectively. Both coefficients are significant at the 0.05 level, but the *t-test* coefficient is not high, thus implying a large variance in the coefficients estimation.

The dummy variable introduced to take into account the direct competition with another airline on the same route has, as expected, a negative coefficient of –0.088. Also in this case, the considerations about the low value of the *t-test* coefficient apply.

The dummy variable introduced to consider flights performed in the week-ends has a coefficient of –0.442. This implies that, other conditions being equal, the demand for air transportation on Saturdays and Sundays is 35.7% lower than in the other days of the week.

Finally, *MAY* dummy variable reveals an 8.3% increase in passenger demand during the month of May respect to February. Moreover, there is a positive trend in passenger demand for air transportation for Air Dolomiti (all other conditions being equal) during these last years.

5 A TWO-LEVEL MODEL FOR AIR TRAVEL DEMAND

According to the analysis of the literature and also to the results of the OLS model estimation performed in Section 4, it turns out that passenger demand for air transportation seems to be elastic with respect to airfares. Then, in order to refine these findings, we study the pattern of variability of price elasticity of demand along the different routes of the airline. In our analysis of Air Dolomiti data, airfare paid by passengers explains more than 30% of the variance in the passenger demand. Therefore, for our qualitative "route-variability" analysis we decided to focus our attention only on the effect of the paid airfares on the passenger demand for air travel on each route. In this framework, the multilevel structure in the data sample must be considered. The final daily passenger demands on each fare-class, that constitute the level 1 units of the population, are grouped in a level 2 units defined by the pertaining route to which demand is referred. Therefore, our model can be seen as a two-level model. The level 2 macro-units are the routes of the airline network, while the level 1 units are the daily demand for a given fare-class on the route. For the analysis of such a model, multilevel statistical methodologies are used [17], as described in the following.

5.1 MODEL SPECIFICATION

The purpose of this investigation is to consider the pattern of variation among the Air Dolomiti routes of price elasticity of passenger demand. To this end, our approach is to consider only the effects of a single predictor x, airfare, to the response variable y, passenger demand. According to the exponential functional form selected in the previous analysis (see subsection 4.1), the two variables are subject to a logarithmic transformation. Since price elasticity is represented by the slope of the regression line in the (x,y) graph, the multilevel functional form selected for the model has to allow both intercepts and slopes of the predicted regression lines to vary across level 2 units. Therefore, the mathematical specification of the model is the following:

$$y_{ij} = a_j + b_j x_{ij} + \varepsilon_{ij}$$

with

$$a_j = a + u_{0j}$$
$$b_j = b + u_{1j}$$

and

$$\begin{bmatrix} u_{0j} \\ u_{1j} \end{bmatrix} \sim N\left(0, \Omega_u\right) : \Omega_u = \begin{bmatrix} \sigma_{u0}^2 & \sigma_{u01} \\ \sigma_{u01} & \sigma_{u1}^2 \end{bmatrix}$$

$$e_{ij} \sim N\left(0, \Omega_e\right)$$

where y_{ijf} is the logarithm of passenger demand for a given fare-class f in the day i on route j and x_{ijf} is the corresponding logarithm of average airfare paid for the transportation. Subscripts j on the coefficients a and b denote that both intercept and slope of the regression line are allowed to vary across the level 2 units, i.e., the different routes.

5.2 EMPIRICAL RESULTS

The empirical results of the multilevel regression analysis are presented in the following equations:

$$y_{ijf} = a_j + b_j x_{ijf} + \varepsilon_{ijf}$$

$$a_j = 8.366(0.483) + u_{0j}$$

$$b_j = -1.031(0.092) + u_{1j}$$

$$\begin{bmatrix} u_{0j} \\ u_{1j} \end{bmatrix} \sim N\left(0, \Omega_u\right) : \Omega_u = \begin{bmatrix} 1.986(0.989) & -0.337(0.178) \\ -0.337(0.178) & 0.072(0.036) \end{bmatrix}$$

$$e_{ij} \sim N\left(0, \Omega_e\right) : \Omega_e = 0.466(0.008)$$

The estimated mean price elasticity coefficient, b, is -1.031 (with a standard error 0.092 indicated within parentheses) and does not differ significantly from the value of -1.058 found in the multiple OLS regression analysis. The individual route slopes vary about this mean with a variance estimated as 0.072 (standard error 0.036). The intercepts of the individual route lines also differ. Their mean is 8.366 (standard error 0.483) and their variance is 1.986 (standard error 0.989). In addition there is a negative covariance between intercepts and slopes, estimated as -0.337 (standard error 0.178), suggesting that routes with higher intercepts tend to have lower slopes (in absolute value). The observed passenger demands vary around their routes' lines by quantities ε_{ijf}, whose variance is estimated as 0.466 (standard error 0.008).

The estimated regression lines for each route are also plotted in the Graph 1 where the x axis represents the logarithm of the average airfare paid and the y axis represents the logarithm of the demand.
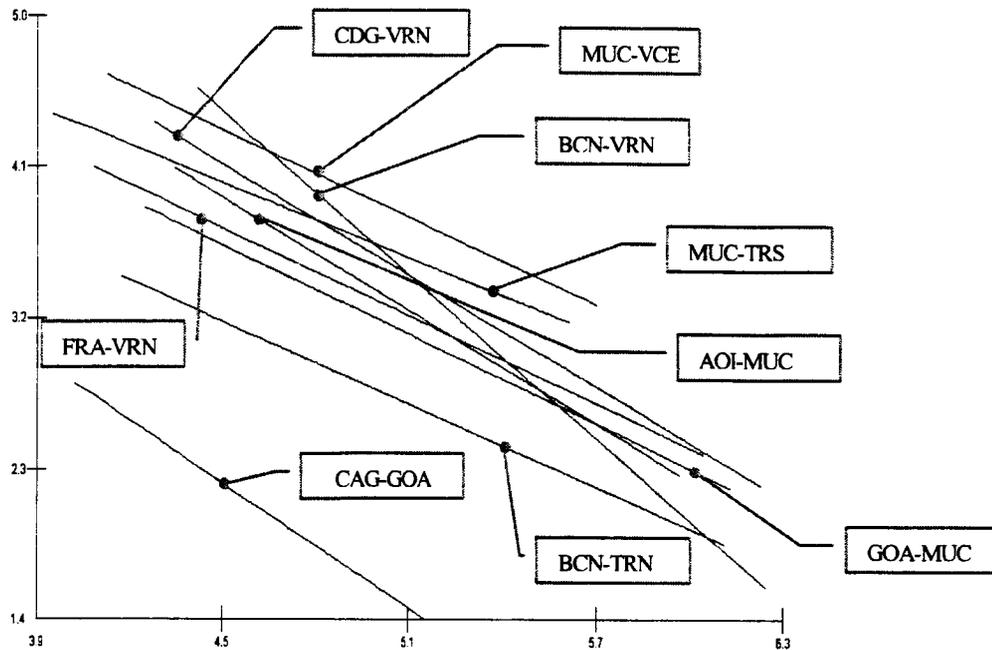
Graph 1: Price elasticity of the demand for each route

The analysis of Graph 1 reveals that demand for flights involving a hub for the airline (Munich or Frankfurt) is relatively more price inelastic than demand for other, point-to-point, routes. This is probably due to the fact that the point-to-point flights attract more leisure travellers, whose price sensitivity is higher. A peculiar case is constituted by the Barcelona-Torino route, which is a point-to-point route for Air Dolomiti and shows a relatively low price elasticity of passenger demand, typical for business routes. This is due to the fact that between the Barcelona and Torino areas there are many important industrial and commercial links, which generate a peculiarly higher demand for business travels between the two cities.

For flights from or to a hub, it should also be considered that a significant fraction (over 40% on the average) of their traffic is transit traffic, in connection with other flights. Then it must be pointed out that the elasticity figures derived in this chapter are based on fares paid for the Air Dolomiti connection only, and not on the total cost of the whole route of transit passengers, which involves other flights, operated by other airlines.

In Table 2 the estimated passenger demand price elasticity coefficients for the various routes are provided.

Route	Estimated passenger price elasticity of demand
Munich-Trieste (MUC-TRS)	-0.746

Barcelona-Torino (BCN-TRN)	-0.821
Munich-Venice (MUC-VCE)	-0.866
Frankfurt-Verona (FRA-VRN)	-0.868
Genova-Munich (GOA-MUC)	-0.884
Paris-Verona (CDG-VRN)	-1.103
Ancona-Munich (AOI-MUC)	-1.122
Cagliari-Genova (CAG-GOA)	-1.243
Barcelona-Verona (BCN-VRN)	-1.624

Table 2: Price elasticity of passenger demand for the various routes

5.3 ANALYSIS OF THE RESULTS

Table 2 shows that there is a great variability among the estimated values of airfare elasticity of passenger demand on the sampled routes ranging from -0.746 for the Munich-Trieste route to -1.624 for the Barcelona-Verona route. In order to investigate in deeper detail the significance of the differences in the airfare elasticity of passenger demand among the different considered routes, the confidence intervals around the values presented in the table above have been studied.

The overall mean slope coefficient (i.e., the airfare elasticity of passenger demand) estimated for the whole data set was –1.031. The residuals, calculated for each route, are defined as the difference between the slope coefficient found for the route (reported in table 2) and the overall mean value; for example, the residual for the Ancona-Munich route was –0.091. Around these residuals (whose mean is zero), the 95% confidence intervals have been calculated. To this end, in [9] and [16] Goldstein, Rasbash *et al.* discussed the circumstances where the value of 1.4 rather the conventional 1.96 standard deviation is used to calculate 95% intervals. They pointed out that to analyse whether a route is significantly different from the overall mean, the conventional 1.96 interval can be used in terms of whether or not it overlaps the zero line. Conversely, if intervals are used to make comparisons between pairs of routes, then we can judge significance at the 5% level by whether or not the 1.4 times standard error intervals overlap.

In Graph 2, the residuals for the slopes are ordered form smallest (-0.593 for the Barcelona-Verona route) to larger (0.285 for the Munich-Trieste route). Then the 1.96 standard deviation intervals are calculated.
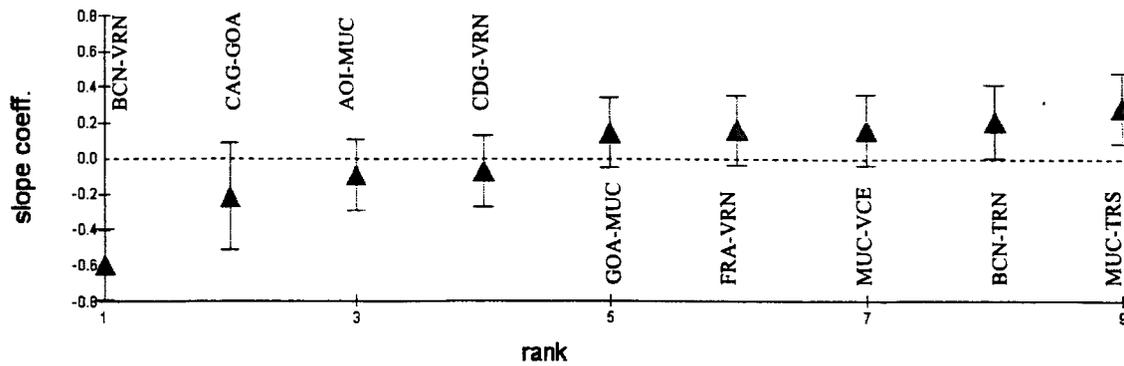
Graph 2: Residual confidence intervals (1.96 standard deviations)

It turns out that the confidence intervals for the Barcelona-Verona route (on the extreme left) and for the Munich-Trieste and Barcelona-Torino routes (on the extreme right) do not overlap the zero line and, therefore, with more than 95% of probability they differ from the overall mean value of -1.031.

If we consider the 1.4 standard deviation, the confidence intervals around the residuals (ordered from smallest to larger, as in the previous case) are presented in Graph 3:
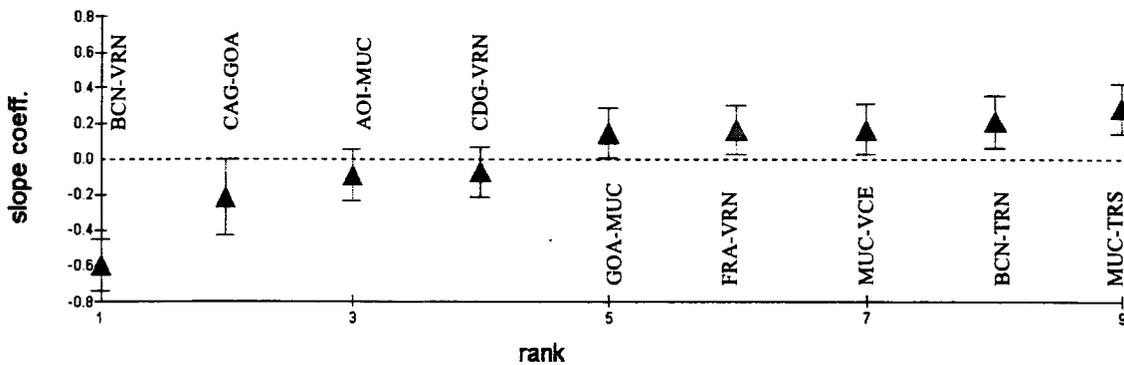
Graph 3: Residual confidence intervals (1.4 standard deviations)

Graph 3 evidences that the routes in the sample could be clustered in three distinct groups, with similar characteristics in terms of airfare elasticity of passenger demand. The first group is constituted by only the Barcelona-Verona route, whose confidence interval does not overlap any other one for the other routes. A second group is constituted by the Cagliari-Genova, Ancona-Munich and Paris-Verona routes, whose slope coefficient is higher than one (in absolute value). The third group is finally constituted by Genova-Munich, Frankfurt-Verona, Munich-Venice, Barcelona-Torino and Munich-Trieste routes, whose price elasticity of demand with respect to airfares is lower than one (in absolute value).

From the analysis of Graphs 2 and 3 we could also note that the Cagliari-Genova route shows larger confidence intervals for the residual than other routes. This is due to the smaller data set used (flights on that route in past years were performed only for two days per week) that also makes the intercept and slope coefficients more "sensible" to outlier observations.

6 CONCLUSIONS

This paper presents an application of an Ordinary Least Squares model to assess passenger air transportation demand for a single airline. The model follows the main guidelines described in the literature taking into account usual drivers affecting passenger air transportation demand. However, the attention is not focused on passenger air travel demand for a given market (as it generally happens, see Section 2), but on the passenger demand of a single airline. The model has been verified and validated on a relatively large sample of flights taken from the Air Dolomiti network. According to the statistical tests performed, the obtained results do not vary from the expected theoretical ones and prove the correctness of the proposed approach.

However, for most airlines passenger price sensitivity may be different (on the average) on different routes. OLS analysis only provides an aggregate view and cannot capture these effects. Hence a multilevel statistical approach has been used to analyse the airfare elasticity of passengers demand on the different routes of the Air Dolomiti data set. The analysis has revealed a significant variability of the elasticity of passenger demand for air transportation with respect to the airfares paid among the different routes of the airline, ranging from −0.746 for the Munich-Trieste route to −1.624 for the Barcelona-Verona route. The study has also been extended through the analysis of the confidence of the results obtained. Their analysis has revealed that the routes in the sample could be clustered in different groups, with different characteristics in terms of price elasticity of passenger demand and, therefore, different expected behaviours of the airline.

The results obtained by the innovative application of the multilevel analysis in the air transportation context seem to be encouraging and suggest to extend the study to more complex models with further explanatory variables and a larger sample of routes. Furthermore, analyses could be led to a more detailed level to investigate, e.g., the effect on fare elasticities of the fact that a larger share of passengers flying to a hub may be expected to continue their journey on other flights, paying a cumulative fare.

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Modeling the effect of enlarged seating room on passengers' preferences of domestic airlines in Taiwan

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Abstract

This study addresses the need for measuring the effect of enlarging seating room in airplane on passengers' preferences of airline in Taiwan. The results can assist Taiwan's domestic air carriers in better understanding their customers' expectations. Stated choice experiment is used to incorporate passengers' trade-offs in the preferred measurement, and three major attributes are taken into account in the stated choice experiment: (1) type of seat (enlarged or not), (2) price, and (3) brand names of airlines. Furthermore, a binary logit model is used to model the choice behavior of air passengers. The findings show that the type of seat is a major significant variable; price and airline's brand are also significant as well. It concludes that air carriers should put more emphasis on the issue of improving the quality of seat comfort.

Keywords: Passengers' preference, Enlarged seating room, Stated choice experiment, Binary logit model.

1. INTRODUCTION

After the deregulation of air transportation market, and due to expectations of increasing demand, most airlines place as many seats as possible in each plane. As a result, the seating space for each passenger, including legroom, arm rest room, and so on, was sacrificed. Consequently, airlines offer a poor standard of passenger comfort service. However, air travelers are concerned about the service quality of seating comfort during their journey in the sky, especially for long-haul trips.

Based on the results of some reports, most airline passengers considered the seat legroom, armrest space, and personal seating room to be quite important. Especially for business travelers, they viewed the quality of seating room as a critical index of the total service quality of airlines (Toynbee, 1994; Flint, 1995). In the study of Alamdari (1999), the author also indicated that airline passengers considered the quality of seating room as one of the important factors when selecting an airline. Fiorino (1999) revealed that the uncomfortable seating configuration in coach class is the root of much passenger discontent. Hence, there are more and more airlines, including United Airlines, American Airlines, British Airways, Virgin, and Singapore Airlines, etc., that direct a lot of effort into reconfiguring seating and expanding legroom so that they can provide better seat comfort to passengers (McDougall, 2002).

In Taiwan, some local researches also showed that the service quality of seating room is one of the most important factors when travelers select a domestic airline. However, the quality of seat comfort that air passengers actually received falls far behind their expectations. Obviously, it can be seen that if airlines in Taiwan pay more attention to improving seat comfort, the passengers may attach higher values of total service quality to an airline, and might change their preference. In other words, the effect of a seating environment should not be ignored when passengers choose an airline.

What is more, due to the gradual decline in passenger load factor in recent years, it appears to be the time to discuss the policy of passenger-maximization thoroughly. In other words, if airlines can decrease the total seat numbers by adjusting the cabin configuration, or rather, enlarging the seating space of each seat, and promote different price strategies, they will probably raise the load factor as well as revenue. The aim of this study is to explore the change in air passengers' preferences, in a situation where service quality has improved (in terms of seating room), through enlarging the size of seat. Stated choice method (Louviere, et al., 2000) is used to administrate an experimental design, that includes three variables (attributes): passenger seat type, price, and brand (airline). Then a binary logit model is used to describe the choice behavior of air passengers. Though the focus of this issue is on Taiwan's domestic air passengers market, the results also can be

applied to the marketing practice of international airlines. Especially those domestic airlines in Taiwan that are well prepared to service the route between Taiwan and Mainland China. Thus the result of this study could provide some positive suggestions for an improvement in passenger service.

This paper is organized as follows: Section 2 describes the background of Taiwanese Domestic Air Passenger Market. Section 3 introduces the stated preference experiment strategy of this study. Section 4 presents and discusses the results of empirical analysis. Finally, Section 5 offers brief concluding comments.

2. BACKGROUND – Taiwan's domestic air passengers market

The air transportation market in Taiwan has grown rapidly over the past two decades, especially after deregulation in 1988. Air transportation in Taiwan services about two percent of intercity traffic. Among them, passengers who make a round trip between Taipei, the political and economical center of Taiwan, and Kaohsiung, the biggest metropolitan city of southern Taiwan, is the major element of air transportation. In 2001, there were almost four million passengers, 33 percent of Taiwanese air transportation traffic, between Taipei and Kaohsiung.

However, in recent years, due to drastic expansion and the falling economic environment, the passenger load factor has gradually declined. In 2001, the passenger load factor was only about 56 percent. The trend described above also can be observed in Fig. 1.
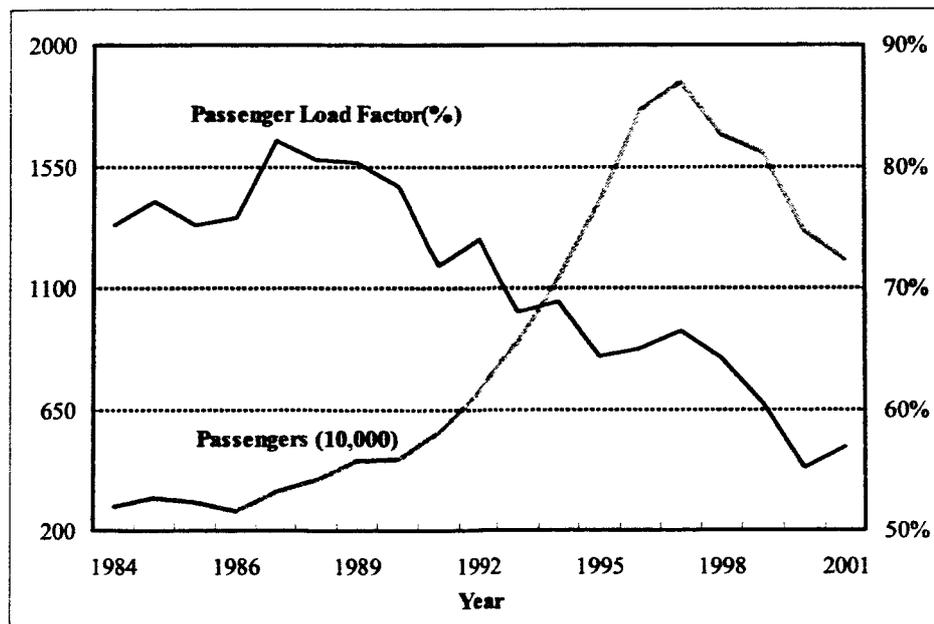
Source: The Statistic Year Book of Civil Aviation, Civil Aeronautics Administration (C.A.A.), 2002.

Fig. 1. The growth trends of the air passengers market in Taiwan.

At present, there are four domestic airlines in Taiwan: Far Eastern Air Transport, Trans Asia Airways, Uni Air, and Mandarin Airlines. Their individual market share of the Taipei-to-Kaohsiung route is shown in Fig. 2. The figure shows that Far Eastern Air Transport dominates the air passengers market on this route, with Trans Asia Airways and Uni Air following behind.

These four domestic airlines provide two classes of cabin configuration, business class and economic class. However, the number of seats on business class is no more than 12 (only about five percent of total seats on each plane). That means that only 12 passengers actually sit in business class on each flight, some times even fewer. Thus nearly 95 percent of domestic passengers have no choice but to sit in the very crowded economy class seats.
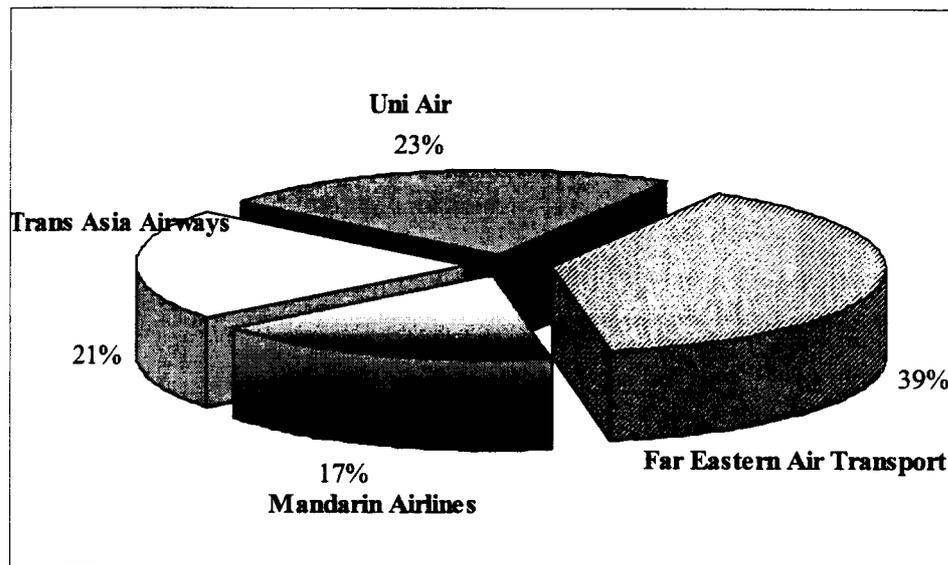
Source: The Statistic Year Book of Civil Aviation, Civil Aeronautics Administration (C.A.A.), 2002.

Fig. 2. The market share: The Taipei-to-Kaohsiung route

Moreover, these business class seats are frequently used as rewards for frequent flyers. Hence, the revenues from business class seats do not do much help to these air carriers.

In short, Taiwan's domestic air passenger market is undoubtedly shrinking. It is necessary to promote new marketing strategies to induce latent demand. Meanwhile, several studies also indicate that the service quality, in terms of cabin seating, is a fairly important factor when air passengers select an airline. As a result, strengthening the service

quality of cabin seating, such as stretch out length; and expanding the width of seating space, should be given a higher priority. Consequently, it is suggested that the policy of enlarging seating room could be a new marketing strategy, and its effects on air passengers' preference of airlines should be analyzed.

3. STATED CHOICE EXPERIMENT

There are many factors that affect passengers' choice of airlines: time schedule, number of flights, frequency, number of direct-flights, airlines image, punctuality, in-flight services, seat comfort, passengers' attitudes, passengers' purpose of trip, and passengers' satisfaction with the airlines, etc. (Proussaloglou and Koppelman, 1995; Ghobrial, 1989; Ippolito, 1981). A conceptual figure, shown in Fig. 3, can describe passengers' choice of behavior. However, the effects of seat comfort and airlines' image are rarely quantified. Hence, the relationship that is presented as solid line in Fig 3 is the major concern of this study. Due to lack of revealed preference of seat comfort for market presence, a stated choice experiment is used to present a choice game and analyze the quantified effects of those variables.
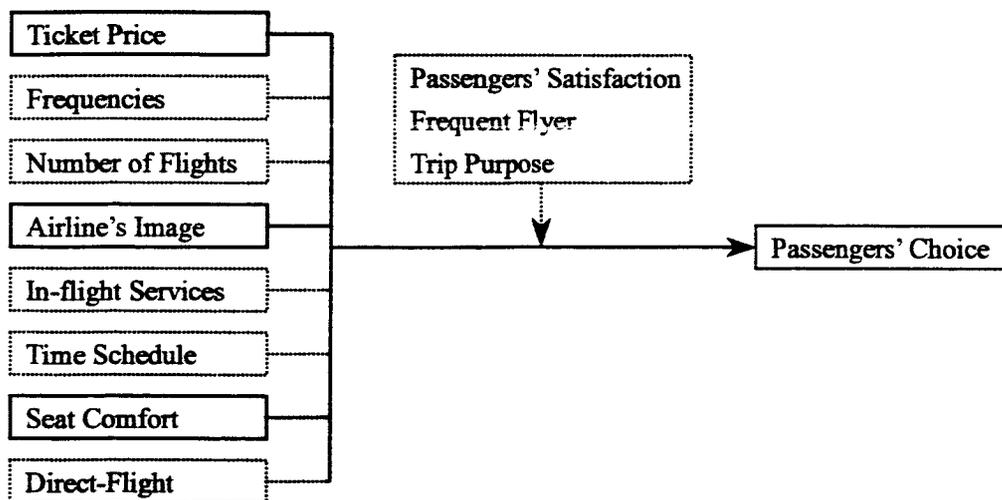
Fig. 3. The conceptual framework of passengers' choice of airlines

Let us first define the attributes and associated levels in the stated choice experiment. Here, we selected three attributes in constructing the stated choice game. The attributes and associated levels are shown in Table 1.

Table 1. Three attributes and associated levels used in the study

Variables	Levels
Seat-Type	(1) The seat-size is the as same as the market practice.
	(2) 50 percent of total seats are enlarged seats.
	(3) 100 percent of total seats are enlarged seats.
Price	(1) 10 percent higher than market average.
	(2) Market average.
Brand	(1) Far Eastern Air Transport.
	(2) Trans Asia Airways.
	(3) Uni Air.
	(4) Mandarin Airlines.

The first attribute is the type of seat, and has three levels: (1) the size of seat is same as market practice and, (2) 50 percent of total seats given on each flight are enlarged seats (the rests are the same as on the standard economic class seat) and, (3) 100 percent of total seats given on each flight are enlarged seats. The second attribute is ticket price with two levels: (1) 10 percent higher than market average and, (2) same as market average. The last attribute is the brand name of airline. As there are four airlines in the domestic air passenger market in Taiwan, four levels of brand name attribute are given as follow, (1) Far Eastern Air Transport (FEAT), (2) Trans Asia Airways (TAA), (3) Uni Air (UA), and, (4) Mandarin Airlines (MAL).

In here, we viewed the alternative represented the airline that passengers originally took as an independent alternative. So the first level of Seat_Type was eliminated from experimental design. That is, the stated choice experiment contained 16 profiles that were generated from the experimental design of $2 \times 2 \times 4$. The respondents had to finish three choice tasks. The first choice task and the second choice task both asked respondents to evaluate the airline that they took originally, and one profile that selected randomly from 16 profiles, respectively. The third choice task asked respondents to evaluate the two profiles that were presented separately in the first choice task and the second choice task. That is, all respondents faced two alternatives on each choice of the game.

The choice game experiment was conducted in a questionnaire, and respondents were randomly selected from the air flight route of Kaohsiung-to-Taipei. In addition to the choice game, socio-economic status and demographic information were also gathered for sample descriptive and further analysis.

Locally hired and trained interviewers were assigned to Kaohsiung Airport, and randomly selected passengers who were going to Taipei, for interviewing. Passengers were interviewed while they were waiting for the flight that they were going to take, and asked to participate in a survey; 576 passengers fully completed the survey.

4. EMPRICAL RESULTS AND DISCUSSION

In this section, we first describe the composition of samples and then analyze the results about passenger choice behavior. We constructed a passenger choice model by the use of binary logit model. Some discussions about the results found are also drawn here.

4.1 Sample Description

Among all the respondents, 60 percent were male, and 40 percent were female. Most respondents were at age 21 to 30 which made up 51.4 percent of all samples; followed by those at age 31 to 40 and 41 to 50. In addition, about 70 percent of all respondents were college or graduate school graduates. Furthermore, almost 30 percent of all respondents were business trip passengers, and 70 percent of all were non-business trip passengers.

Respondents were also asked what class of seat they took / were taking. The results showed that 88 percent of all respondents took economic class seats, and 12 percent of respondents took business class seats, meanwhile, only half of business class passengers (that is six percent of all respondents) paid full price.

Furthermore, over 85 percent of the respondents were unsatisfied with the seating situation currently provided on domestic flights. The major factors leading to their dissatisfaction were nothing more than lack of stretch out space, strained arm rest room, and the oppression caused by those lower overhead compartments. On the other hand, nearly 90 percent of the respondents would prefer an airline with larger and more comfortable seating configuration if their travel time became twice as the present time.

4.2 Affecting Factors on the Passengers' Choice of Airlines

After we referenced several studies related to passengers' choice of airline, we listed 10 possible affecting factors on choice of behavior. Respondents were asked to rank these factors using the numbers 1, 2, and 3 to represent 'Very important', 'Important', and 'Less important'. Then a score of three was assigned to 'Very important', two to 'Important', and score of one to 'Less important'. As a result, total score of each affecting factor and rank the importance of these factors can be calculated. Table 2 was the result of importance ranking of affecting factors.

Table 2. Importance of affecting factors on passengers' choice decision

Affecting Factors	Total	Importance Ranking Business Passengers	Non-Business Passengers
Schedule of Time Table	1	2	1
Safety	2	1	2

Ticket Price	3	4	3
Seat Comfort	4	3	6
Airlines Image	5	5	5
Punctuality	6	9	4
In-Flight Service	7	10	7
Frequent Flyer Member	8	8	8
Reservation and Check-in Service	9	7	9
Aircraft Type	10	6	10

From the results showed in Table 2, it is clear that the top two factors affecting passengers' choice of airline are 'Schedule of Time Table' and 'Safety'. The factor of 'Seat Comfort' is ranked fourth by the total number of passengers, third for business passengers, and sixth for non-business passengers. It means that business passengers view the effect of seat comfort on their choice decision as more important than non-business passengers. Also, most passengers give more consideration to the quality of seat comfort when they select an airline. Therefore, if air carriers are willing to make more improvements in terms seating space on their fleet, this may bring some positive benefits in terms of passengers' choice.

Moreover, it also can be seen that the importance ranking of all affecting factors is quite different between business passengers and non-business passengers, especially for the factor of 'Punctuality'. It is ranked ninth for business passengers and fourth for non-business passengers. This result is different from expectations that business passengers would put more emphasis on the importance of 'Punctuality'. One possible reason of that is business passengers may mostly be frequent flyers, so they are familiar with flight schedule information, and realize that the quality of punctuality is quite good for market practice.

4.3 Analysis of Passengers Satisfaction

The analysis of passengers' satisfaction can help us know the quality of airline services that passengers actually received. Ten service factors were selected and respondents were asked to separately evaluate their satisfaction of these service factors that they received by the use of five-point scale: 'Very good', 'Good', 'Moderate', 'Bad', and 'Very bad'. Next, five different scores were assigned, from a maximum of five to a minimum of one, to represent five-point scale sequentially. After calculating the total scores of each service factor, the results are shown in Table 3.

Table 3. Ranking of passengers satisfaction of service factors

Service Factors	Ranking	Mean Score	Standard deviation
Reservation and Check-in Service	1	3.67	0.61
Flight Attendant Service	2	3.57	0.69
Safety	3	3.39	0.77
Punctuality	4	3.27	0.74
Responsible for Complaints	5	3.24	0.57
Schedule of Time Table	6	3.21	0.68
Aircraft Type	7	3.12	0.62
Ticket Price	8	2.90	0.74
Seat Comfort	9	2.86	0.78
In-Flight Catering Service	10	2.82	0.74

The ten service factors presented in Table 3 are a little bit different from the ten affecting factors presented in Table 2. 'Frequently Flyer Member' and 'Airline Image' are deleted from the set of affecting factors, and the service factor of 'Responsible for Complaints' is added. The affecting factor of 'In-Flight Service' is divided into two: 'Flight Attendant Service' and 'In-Flight Catering Service'.

A study of the results of Table 3 shows that the service factor of 'Seat Comfort' is ranked far behind the other eight service factors. Also, its mean score is 2.86, indicating that the service quality that passengers received was under average. Compared to the results of Table 2, it obviously implies that there is a service gap between passengers' expectation and what is received. Again, it can be seen that the improvement of the quality of seat comfort should be advanced to the most important place. As a result, there will be positive effects in terms of the passengers' satisfaction.

In addition, each score of service factors segmented by airline, is summarized, to obtain the total scores of passengers' satisfaction with the airlines. The rankings of Taiwan's domestic four airlines are presented in Table 4. The results of Table 4 suggest that Trans Asia Airways (TAA) is the first ranked, implying that most passengers are satisfied with the services offered by TAA. The second ranked airline is Far Eastern Airline (FEAT). TAA and FEAT made up almost 60 percents of total air traffics in the route of Taipei-to-Kaohsiung in 2002.

Table 4. Ranking of passengers' satisfaction with airlines

Airlines	Ranking
Trans Asia Airways (TAA)	1
Far Eastern Air Transport (FEAT)	2
Uni Air (UA)	3

4.4 Choice Model

In order to quantify the effects of improving seat comfort on passengers' preference of airline, a binary logit model is used to construct a passenger choice model. The variables that were taken into account are shown in Table 5. Among them, there are the types of seat as two dummy variables: Seat-Type 1 represented the level of 50 percent enlarged seats, and Seat-Type 2 represented the level of 100 percent enlarged seats (the reference level is same as market practice). Also, the brand names of airlines are set as three dummy variables: TAA represented Trans Asia Airways, FEAT represented Far Eastern Air Transport, and UA represented Uni Air (Reference level is Mandarin Airlines). The results of this choice model are shown in Table 6.

Table 5. The definition of variables

Variables	Definition
Price	Quantified variable. Ticket Price (Unit: 1,000 NT$)
Seat_Type 1	Dummy variable. If the seat-size is 50 percent enlarged seats, the value of it is 1, otherwise is 0.
Seat_Type 2	Dummy variable. If the seat-size is 100 percent enlarged seats, the value of it is 1, otherwise is 0.
FEAT	Dummy variable. If the brand name of airline is Far Eastern Air Transport, the value of it is 1, otherwise is 0.
TAA	Dummy variable. If the brand name of airline is Trans Asia Airways, the value of it is 1, otherwise is 0.
UA	Dummy variable. If the brand name of airline is Uni Air, the value of it is 1, otherwise is 0.

The results in Table 6, signal that all variables are quite significant, although the variable of UA was less significant. However, the index of goodness-of-fit of this model is weak. The value of likelihood ratio is only 0.05.

Table 6. Results of passengers' choice model of airlines

Variables	Coefficients	t-value
Constant	0.786	4.184
Price (1,000 NT$)	-0.568	-2.457
Seat_Type 0	Reference Level	
Seat_Type 1	0.724	3.585
Seat_Type 2	1.233	4.631
FEAT	0.381	2.159
TAA	0.620	3.287
UA	0.294	1.575

MA	Reference Level
Samples	576
Log Likelihood at Convergence	-379.302
Likelihood Ratio (ρ^2)	0.05

The sign of price is negative implying that passengers prefer the airline of lower ticket fare to that of higher ticket fare. The sign of dummy variables of Seat_Type 1 and Seat_Type 2 are positive indicating that there are positive effects of enlarged seats on passengers' choice of airline. This result supports inferences before: that passengers actually view seat comfort as an important factor on their choice decision. In addition, it is noted that the coefficient of Seat_Type 1 is smaller than that of Seat_Type 2. It means that the effect of 100 percent enlarged seats on passengers' choice is greater than that of 50 percent enlarged seats. Furthermore, t-test could be used (see the following equation) to test if the null hypothesis that these two coefficients are equal is accepted.

$$t = \frac{\beta_2 - \beta_1}{\sqrt{Var(\beta_1) + Var(\beta_2) - 2Cov(\beta_1, \beta_2)}} \tag{1}$$

In the equation (1), β_2 means the coefficient value of Seat_Type 2, and β_1 represents the coefficient value of Seat_Type 1. According to this equation, the t-value is 3.216. It is significant compare to the critical value of 1.96 ($\alpha = 0.05$). This result implies that the effect of 100 percent enlarged seats on passengers' choice of airline is significantly different from that of 50 percent enlarged seats.

Finally, the variables of brand names of airlines are also significant. The variable of TAA that represents Trans Asia Airways has the greatest coefficient value. The second and third values of coefficients are FEAT and UA. It implies that passengers who took TAA would have stronger preferences toward TAA than passengers who took FEAT and UA. These factors are in concord with the passengers' satisfaction of airlines that was illustrated in the previous section.

5. CONCLUSION

In this research the effect of enlarged seats on passengers' preferences of airline was measured, it has been shown that enlarged seats do affect the choice decision of air passengers. These findings indicate that air passengers would like to choose the airlines that have the most enlarged seats, and air carriers should take the issue of seats rearrangement into consideration.

In addition, price is also a significant affecting variable. Although most studies, such as Ghobrial (1989), Ippolito (1981), and Yoo and Ashford (1996), etc., indicate that ticket price may not play a significant role in air passengers' choice, because there is not much difference in ticket price between airlines. However, a stated choice experiment was used to show the possible varieties of ticket price, and found that ten percent price range could affect passengers' choice significantly; nevertheless, the cross effects between seat-type and ticket price is not considered here. Generally speaking, air passengers who paid higher price should receive higher quality of seat comfort. That is, there is a little positive relationship between seat-type and price. In this study, it is supposed that any relationship between seat-type and price does not exist. Therefore, there is no analysis of the cross effect between enlarged seats and ticket price. This should be taken into consideration in a future study.

Finally, the variables of brand names were used to measure the effect of passengers' satisfaction with the airlines on choice decision. The findings imply that there is positive relationship between passengers' satisfaction and choice decision. In other words, the higher satisfaction passengers receive from a specific airline, the higher probability passengers choose that airline again. Hence, it also can be used to measure the passengers' loyalty to specific airline.

In spite of this, the study focuses on the passengers group in Taiwan, the findings of this study could also be applied to the international air market. It has been found that there are several international airlines that are gradually improving seat comfort in their airplanes. The usual way of upgrading the quality of seat comfort is by enlarging the seating room. Through this study, it may be concluded that enlarged seats could be an efficient marketing strategy.

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AIRPORT CHOICE IN SAO PAULO METROPOLITAN AREA: AN APPLICATION OF THE CONDITIONAL LOGIT MODEL

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Abstract

Using the conditional LOGIT model, this paper addresses the airport choice in the Sao Paulo Metropolitan Area. In this region, Guarulhos International Airport (GRU) and Congonhas Airport (CGH) compete for passengers flying to several domestic destinations. The airport choice is believed to be a result of the tradeoff passengers perform considering airport access characteristics, airline level of service characteristics and passenger experience with the analyzed airports. It was found that access time to the airports better explain the airport choice than access distance, whereas direct flight frequencies gives better explanation to the airport choice than the indirect (connections and stops) and total (direct plus indirect) flight frequencies. Out of 15 tested variables, passenger experience with the analyzed airports was the variable that best explained the airport choice in the region. Model specifications considering 1, 2 or 3 variables were tested. The model specification most adjusted to the observed data considered access time, direct flight frequencies in the travel period (morning or afternoon peak) and passenger experience with the analyzed airports. The influence of these variables was therefore analyzed across market segments according to departure airport and flight duration criteria. The choice of GRU (located neighboring Sao Paulo city) is not well explained by the rationality of access time economy and the increase of the supply of direct flight frequencies, while the choice of CGH (located inside Sao Paulo city) is. Access time was found to be more important to passengers flying shorter distances while direct flight frequencies in the travel period were more significant to those flying longer distances.

Keywords: Airport choice, Multiple airport region, Conditional LOGIT model, Access time, Flight frequencies, Passenger experience with the analyzed airports, Transportation planning

1.Introduction

The air transportation long term rising trend increases the regions worldwide served by more than one airport: the so-called "multiple airport regions". The study of the tradeoffs passengers face when flying out of these regions has therefore become a relevant subject in transportation planning.

In the multiple airport regions, the criteria used by passengers when they make their choice of departure airport constitute an important issue to several professionals, as follows:

1)The Air Transportation Authority: Because its mission is to study, orient, plan, control and motivate the Public and Private Civil Aviation activities, the segmentation of the market of passengers according to flight duration enables this organization to evaluate the importance of access time to the airport placed by the passengers and therefore enables scheduling of flights in the regional airports according to flight duration.

2)The Airport Managers: Searching for anticipated operational efficiency (such as a more consolidated terminal and high levels of passenger occupancy), they are worried with the capital destination to execute improvements rated as priorities by the air passengers, in special those that define the passenger choice of airport.

3)The Airlines: Aiming at a maximum seat factor at their aircrafts, the airport choice research enables the correct capital destination to schedule regular flights (aircraft allocation), distributing the flights among the airports in the multiple airport region according to the preferences pointed out by the passengers.

4)Urban Transportation Planners: These professionals are interested in becoming aware of the passengers' preferences for airports from the point of view of accomplishing public constructions that include improvement of accessibility to the airports, by means of railways or motorways, from the centers where the air transport demand originates.

The overwhelming majority of researchers on airport choice found two kinds of variables satisfactorily explaining the airport choice in a multiple airport region: one variable related to the accessibility to the competing airports and another variable accounting for the air transport level of service provided by these terminals.

This paper aims to determine which variables from a set of candidates have the best explanatory power on the airport choice made by the passengers whose travel starts in the Sao Paulo Metropolitan Area, as well as providing an analysis of the importance placed by the passengers on these variables when passengers are grouped by chosen airport and flight range.

The region of study is well served by two airports: Sao Paulo International Airport (GRU) and Congonhas Airport (CGH). They stand out in the brazilian air transport system

in terms of the volume of embarked and disembarked passengers and compete for the air passengers for numerous domestic destinations.

This paper extends the research on airport choice by presenting and discussing results achieved in the analysis of airport choice in some multiple airport regions worldwide and bringing about results for the Sao Paulo Metropolitan Area.

2.Literature

With a LOGIT model, Skinner (1976) studied the airport choice in Baltimore-Washington. Building utility functions combining airline level of service measures and ground accessibility measures, the signals found for the variables were those expected. Skinner (1976) concluded that: a)The preferred level of service measure was the number of flight frequencies whereas the access utility (a combination of cost and time) was the best measure of ground accessibility; b)Non-business passengers are more worried about accessibility and/or less worried about the supply of flight frequencies; c)To shift the passengers' airport choice, an airport would have to supply an extremely higher amount of flight frequencies in relation to the competing airport; d)A ground accessibility improvement would be a positive policy to shift the passengers' airport choice if it were directed to the entire urban area.

Augustinus and Demakopoulos (1978) analyzed the airport choice in New York-New Jersey. To model the airport choice, they used a model that associates the probability that a passenger chooses an airport to the ratio between: a)The ratio of the costs associated to the cheapest airport over those associated to the chosen airport; b)The sum of the ratios of the costs of the cheapest airport over those of the alternative airports. These quotients a) and b) are previously powered by an exponent α that aims to capture the importance placed by passengers regarding cost differences between airports. In this model, the cost variable enhanced time cost and money cost. Augustinus and Demakopoulos (1978) concluded that access and factors related to convenience are more significant to passengers in short-haul flights, probably because they account for a higher percentage in the door-to-door travel time.

Harvey (1987) studied the airport choice in San Francisco Bay Area, using LOGIT model. He used as modeling variables: access time to the airport, absolute and relative (without connections) flight frequencies. Models exhibiting different formats were built, taking the variables either in their direct value or belonging to a parabolic function, the latter aimed at denoting the decreasing character of the rise in importance of the variable, whenever it was suitable. Harvey (1987) concluded that: a)From a certain supply of flight frequencies, an increase in this supply doesn't seem to make an airport more attractive; b)Direct flights are better regarded than connecting ones; c)the marginal disutility of the access time appears to decrease towards a rise in total time (inferred as total time of access); d)The importance passengers place on access time seems to vary across flight ranges; e)The airport choice seems to be dissociated from the access mode choice; f)For non-business passengers, both flight frequencies and access time are less important.

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Ashford e Benchemam (1987) performed the analysis of the airport choice in Central England, using LOGIT model. The selected variables were: 1) access time from the origin of the travel to each airport; 2) daily flights to the chosen destination; 3) economy fare. The market of passengers was segmented in domestic, business international, leisure international and inclusive tours international. The variable "fare" was excluded from the analysis for business and inclusive tours because its parameter was positive. For business passengers and inclusive tours, the access time was found to be a dominant factor in comparison to flight frequencies, whereas the fare was found to be a dominant factor for domestic and leisure passengers. It was concluded that non-business passengers place more importance on the access and less importance on the flight frequencies in comparison with business passengers.

Innes and Doucet (1990) studied the airport choice in the north of New Brunswick province, Canada, using binary LOGIT model through LOGIST procedure. Variables associated with the air transport level of service and access distance were tested. However, since the signal of the parameter of the access distance variables was positive, these variables were excluded from the modeling. Among the models considering only level of service variables, the variable "aircraft type" was more important to residents, who traveled significant distances in search of a jet service. Other relevant variables were "difference between flight durations" and whether direct flights were offered to the passenger's destination or not. The passengers rejected commuter service, choosing airports with direct flights even when located farther, to an extent that this service was discontinued after this study.

Windle and Dresner (1995) studied the airport choice in Baltimore-Washington D.C., using multinomial LOGIT model, inferring that: 1)The access time was more important to business passengers; 2)The weekly flight frequencies are better regarded by the non-residents in the region; 3)The weekly flight frequencies are more important to business passengers; 4)The inclusion of a variable accounting for the experience with DCA (National) and IAD (Dulles) airports decreases the probability of choosing BWI (Baltimore-Washington Intl' airport) and the importance of the access time; 5)Duplicating the previous result, but only for passengers that accessed the airport with motor vehicles, it was noted more importance placed on access time; 6)Passengers originating from zones with fairly equivalent access time place more importance on weekly flight frequencies and less importance on access time, not depending on the market segment; 7)The passengers' experience with an airport is generally an important determinant of the airport choice.

Pels, Nijkamp and Rietveld (1998) studied the conjoint choice of airport and airline in the San Francisco Bay Area, using nested LOGIT model, building two situations of sequential choice: 1)First airport choice and then airline choice; and 2)First airline choice, followed by airport choice. Pels, Nijkamp and Rietveld (1998) didn't find expressive difference in the estimations of the utility function between business and non-business passengers. These parameters seemed to vary more across time than across market segments. Anyway, they concluded that the estimated parameters were rather robust. Moreover, they concluded that the airport choice happens first, and then the airline choice, not being simultaneous choices.

Researches treating the same region in different years showed distinct passengers' appraisal on accessibility and level of service measures, in terms of market segments grouped by travel purpose. As a result, the evolution of passenger behavior across time indicates the demand for seasonal researches on airport choice in the same multiple airport region.

3.Model

The LOGIT model has been the most widely used model to cope with multiple choice situations in transportation engineering, especially in the majority of the papers analyzed in the previous section. To build the LOGIT model, some considerations related to the passengers' choice process are imperative.

Each passenger presents a consistent structure of preferences, based on the utility each alternative choice can provide, in a way that the passenger chooses the option (airport) whose utility is the maximum among the available choices. This choice behavior can be expressed mathematically by the following inequation:

$$U_{mi} \geq U_{ni} \text{ for all n, } 1 \leq n \leq z \qquad (1)$$

Where: U_{mi} is the utility that passenger i obtains by choosing airport m, U_{ni} is the utility that passenger i obtains by choosing airport n, z is the number of airports (alternatives) available for choice.

Since the perception of the attributes that each alternative offers may vary widely from passenger to passenger, and even the characteristics usually measured being constant for two different passengers, the utility of each alternative airport is not regarded from the same standpoint, therefore it is wise to include a random element to the travel choice, that is added to the deterministic one, forming the theoretical basis for the stochastic choice. The stochastic formulation of the utility function is expressed as:

$$U_{mi} = D_{mi} + R_{mi} \text{ for all m, } 1 \leq m \leq z \qquad (2)$$

Where: U_{mi} is the utility that passenger i obtains by choosing airport m, D_{mi} is the deterministic part of the utility function for alternative m chosen by passenger i, R_{mi} is the random part of the utility function for alternative m chosen by passenger i, z is the amount of choices considered available for passenger i.

The LOGIT model assumes that the random components of the utility function are independent and identically distributed with a Gumbel function (double exponential) as Kanafani (1983) explains. The probability function that denotes the choice of an alternative is given by:

$$p_m (D_1, ..., D_m, ..., D_z) = \frac{e^{\alpha.D_m}}{\sum\limits_{z=1}^{z} e^{\alpha.D_z}} \tag{3}$$

Where: p_m is the choice probability of the alternative m (each alternative is an airport in this paper), among the z alternatives (airports); D_m is the deterministic part of the utility function of alternative m (airport); α is the parameter associated with the deterministic part of the utility function.

While at an individual level the formulation predicts the probability that a passenger chooses the airport in question, at an aggregate level it predicts the share of the considered airport.

To accomplish the estimation of parameter α, NLOGIT program version 3.0 was used, available in the LIMDEP program version 8.0 produced by the company Software Econometric, Inc. The reference guide of this software classifies the multinomial LOGIT models:

1)Models whose variable values are input the same across all alternatives for the same observation (passenger), as they are individual characteristics; .

2)Models whose variable values are attributes of the alternatives (perceived by passengers), and variables whose value remain constant across alternatives (for the same passenger) are also allowed.

The latter is the model that this paper employed, also known as conditional LOGIT model, which estimates variable parameters using the Maximum Likelihood Method. For the iterations, Newton Method was used because it produced quick convergence for all calibrated models.

The goodness-of-fit measure generated by the Conditional LOGIT model of this software is called R^2 ($0 \leq R^2 \leq 1$). However, the percentage of passengers whose actual choice is similar to the one the model predicts is given by the fraction of concordant pairs (and not by the value of R^2, as the users of linear regression may think).

4.Case Study

Although the Sao Paulo Metropolitan groups several towns, 7 of them (Sao Paulo, Guarulhos, Santo Andre, Sao Bernardo do Campo, Sao Caetano do Sul, Diadema e Osasco) have been chosen to represent the trip origin in this region, because of two reasons:

a)They represent 79% of the electric power consumption in the region;

b)The calculation of the access time from the other towns wasn't likely to lead to sound values.

The alternative airports whose choice was analyzed were Congonhas Airport (CGH, located in Sao Paulo city) and Guarulhos Airport (GRU, located in Guarulhos city, neighboring Sao Paulo). The criteria for destination selection was that there must have been departures to these destinations from both airports and that the annual volume of passengers must have surpassed 100,000 passengers. This volume, as Windle and Dresner (1995) tell, avoids small sample bias, that usually represent less popular destinations. These two requisites were evaluated through the last statistical report of the DAC (Department of Civil Aviation) available to the date of data collection, the report of the year 2000.

Therefore 21 airport destinations (19 cities) were studied in this paper: 1)BPS (Porto Seguro); 2)BSB (Brasilia); 3)CGR (Campo Grande); 4)CNF (Belo Horizonte); 5)CWB (Curitiba); 6)FLN (Florianopolis); 7)FOR (Fortaleza); 8)GIG (Rio de Janeiro); 9)GYN (Goiania); 10)IGU (Foz do Iguacu); 11)JOI (Joinville); 12)LDB (Londrina); 13)NVT (Navegantes); 14)PLU (Belo Horizonte); 15)POA (Porto Alegre); 16)RAO (Ribeirao Preto); 17)REC (Recife); 18)SDU (Rio de Janeiro); 19)SSA (Salvador); 20)UDI (Uberlandia); 21)VIX (Vitoria);

The passenger profile was obtained by revealed preference interviews at the airports, conducted during the weekdays of two consecutive weeks (February 8th to March 1st, 2002, during the peak hours of access to airports, i.e., from 7 AM to 10 AM (morning peak) and from 5 PM to 8 PM (afternoon peak).

These periods were chosen because the average vehicle speeds in Sao Paulo city have been measured during these periods by CET (Traffic Engineering Company), enabling the calculation of access time to the airports.

Aiming at a maximization of the explanatory power of the collected data and minimization of time and cost of data collection, compilation and analysis, 1923 passengers were interviewed, being 897 at GRU and 1026 at CGH. This amount of observed data has been considered satisfactory taking into account the paper of Koppelman and Chu (1985) who calculated the amount of observations required for relatively simple disaggregate choice models.

The revised literature tends to classify the passenger market in a way that enables inferences on the departing airport choice made by homogeneous passenger segments. Table 1 presents the results of the interviews according to market segmentation criteria.

5.Airport choice: explanatory variables

Three types of variables were chosen to be tested: those associated with the ground accessibility to the airports, those related to the airlines' level of service in the airports and the last one is associated with the passenger experience with the airports in the studied region.

Table 1: Results of the interview with passengers

Sample segmentation criteria	Passenger market segments
Departing period	853 departing in the morning peak and 1070 in the afternoon peak
Departing airport	897 departing from GRU and 1026 from CGH
Travel purpose	1400 business and 523 non-business
Place of residence	937 residents and 986 visitors
Age	975 under 37 years old and 948 over 37
Household monthly income	1024 under R$ 6,000.00 monthly wage and 899 over R$ 6,000.00
Passenger experience with the airports in the region	946 under 7 flights during the year 2001 and 977 over 7
Access mode	127 accessing by bus and 1745 accessing by taxi or car (either hitchhiking or driving)
Declared reasons for choosing the departing airport	290 didn't know that there were flights at the competing airport to the desired destination; 287 choice was made by a third party; 902 choice by proximity and 460 choice by the supply of more flight frequencies to the desired destination.
Flight range	1116 in flights with flying time up to one hour and 807 in longer flights
Type of airline chosen	1883 using regular cost airlines and 40 using low cost airlines

Using the conditional LOGIT model, the utility function of an alternative was designed as the summation of the effects of the variables pre-multiplied by a parameter whose estimation is one of this paper's goals. The model built was abstract, e.g., the coefficients of the variables were the same for both alternative airports, GRU and CGH.

Each passenger i, $1 \leq i \leq 1923$, has been represented by two generic decision functions, being the first always for GRU and the second for CGH, whichever the departing airport, as follows:

$$CHOICE_{i\,GRU} = \alpha_1.ACCESS_{i\,GRU} + \alpha_2.FREQUENCY_{i\,GRU} + \alpha_3.EXPERIENCE_{i\,GRU} \qquad (4)$$

$$CHOICE_{i\,CGH} = \alpha_1.ACCESS_{i\,CGH} + \alpha_2.FREQUENCY_{i\,CGH} + \alpha_3.EXPERIENCE_{i\,CGH} \qquad (5)$$

Below the choice probability of each airport by each passenger is shown:

$$p_{i\,GRU} = \frac{exp(CHOICE_{i\,GRU})}{[\,exp(CHOICE_{i\,GRU}) + exp(CHOICE_{i\,CGH})\,]} \qquad (6)$$

$$p_{i\,CGH} = \frac{\exp(CHOICE_{i\,CGH})}{[\exp(CHOICE_{i\,GRU}) + \exp(CHOICE_{i\,CGH})]} \qquad (7)$$

Where: ACCESS is a variable associated with the access to the airports; FREQUENCY is a variable associated with the airlines' level of service; EXPERIENCE is a variable related to the passenger's experience with the airports in the region; $p_{i\,GRU}$ is the probability that passenger i chooses GRU; $p_{i\,CGH}$ is the probability that passenger i chooses CGH; CHOICE is a decision function of airport choice; α_k is the parameter (coefficient) related to the variable k, being k=1 for ACCESS, k=2 for FREQUENCY and k=3 for EXPERIENCE.

5.1. Variables associated to the access to the airports (ACCESS)

Since 100% of the passengers faces the tradeoff between the access distances (AD) to the alternative airports, this variable was tested, being expressed in km.

The access time (AT) by auto mode (in this paper denoted by "general traffic") was the variable most widely used in the analyzed literature. Because 1745 passengers (91%) face the tradeoff between access times to the competing airports using general traffic when they make an airport choice, this variable was tested, its value being expressed in minutes.

To calculate the access time to each airport, the studied region was sectioned in 101 zones (95 in Sao Paulo city and the other 6 towns constituted, one by one, other 6 zones). The access distances from the centroids of the zones were measured considering the access by the existing streets, avenues and roads.

The average speeds along the main streets and avenues were extracted from the CET (Traffic Engineering Company) annual reports, years 2000 and 2001. These speeds were grouped by access mode: bus and general traffic, and they account for the period of the day: morning peak hours (7 AM to 10 AM) and afternoon peak hours (5 PM to 8 PM). Data from different years were used as a matter of availability and updating at the time of their collection. This didn't pose a problem because there were no significant modifications in the access to the airports from the first year considered until the period of interview with the passengers.

Regarding the streets and avenues whose speed was not available, average values of the measured ones were adopted, weighing by length of the street or avenue, and considering the period of the day. For highways, a value of 80 km/h was adopted, irrespective of the period of the day.

5.2. Variables associated the airlines' level of service in the airports (FREQUENCY)

Among the level of service variables, flight frequencies were the most commonly used in the analyzed literature, and a satisfactory explanatory power was verified, therefore 12 flight frequencies-related variables have been tested.

These variables were built in terms of the following criteria: 1)The existence of connections or stops (direct flights, indirect flights and the sum of the two); 2)The travel period (morning peak or afternoon peak); 3)The day of the week.

In terms of the second criterium, the passengers were interviewed at the moments prior to their departure, at times before their proceeding to the waiting room and sometimes after. The morning peak was considered from 7 AM to 10 AM and the afternoon peak from 5 PM to 8 PM. Albeit the data collection was after the access to the airport, it was admitted that close to the peak periods (no matter before or after them) the highway access speeds do not vary at a significant basis from the peak periods themselves.

The flight frequencies across periods of the day and across days of the two weeks when the interview took place were determined through the Internet websites of the airlines that offer regular flights and operate at the competing airports. Although the interviews had taken place during the weekdays, weekend flight frequencies were also accounted for since they increase the utility associated with the alternative airport where they are supplied.

For each of the built variables of frequency, its value was collected for the chosen airport and the airport not chosen. Below these variables are presented: 1)DDPF: Direct frequencies in the travel day and period; 2)DDF: Direct frequencies in the travel day; 3)DPF: Direct frequencies in the travel period (morning or afternoon peak) in all days of the week when the passenger traveled; 4)DWF: Direct weekly frequencies irrespective of day and period; 5)IDPF: Indirect (with connections or stops) frequencies in the travel day and period; 6)IDF: Indirect frequencies in the travel day; 7)IPF: Indirect frequencies in the travel period (morning or afternoon peak) in all days of the week when the passenger traveled; 8)IWF: Indirect weekly frequencies irrespective of day and period; 9)TDPF: Total (direct plus indirect) frequencies in the travel day and period; 10)TDF: Direct frequencies in the travel day; 11)TPF: Direct frequencies in the travel period (morning or afternoon peak) in all days of the week when the passenger traveled; 12)TWF: Direct weekly frequencies irrespective of day and period.

Consider a passenger that departed to a given destination in the morning peak of February 19th, 2002. The variables of direct flight frequencies are shown in Table 2, and the variables of indirect and total flight frequencies were built in an analogous way:

Table 2: Variables of direct flight frequencies

	18	19	20	21	22	23	24	Total
	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
Up to 7h								
7h-10h		DDPF						DPF
10h-17h								
17h-20h								
After 20h								
Total		DDF						DWF

Most flights to Rio de Janeiro central airport, Santos Dumont (SDU), depart from Sao Paulo central airport, Congonhas (CGH), whereas most flights to Rio de Janeiro international airport, Tom Jobim (GIG), far from the city center, depart from Sao Paulo international airport, Guarulhos (GRU), which neighbors Sao Paulo city.

In the same way, most flights to Belo Horizonte central airport, Pampulha (PLU), depart from Sao Paulo central airport, Congonhas (CGH), whereas most flights to Belo Horizonte international airport, Confins (CNF), far from the city center, depart from Sao Paulo international airport, Guarulhos (GRU), which neighbors Sao Paulo city.

For these reasons, a question on the reasons for airport choice in the interview with the passengers included whether the passenger chose the airport of departure because a considerable surplus of flight supply to the desired destination airport in case the passenger destination was also a multiple airport region (Rio de Janeiro and Belo Horizonte). In case the passenger answer was positive, frequencies to the other airport in the multiple airport region of destination were not included in the several variables of flight frequencies. For instance, a passenger flying to Rio de Janeiro and departing from CGH, if he declared his airport choice because he prefers to arrive at SDU, frequencies to GIG, the competing destination airport, were not considered no matter they were supplied at GRU or CGH.

5.3. Variable related to the passenger experience with airports (EXPERIENCE)

Windle e Dresner (1995) used this variable, showing that incorporating a variable that accounts for the passenger experience with an airport of departure in the studied region (in this case the number of times that the passenger departed from each airport in the region during the previous year), the importance placed on access time and weekly flight frequencies decreases, irrespective of the market segment (they segmented the market by travel purpose and place of residence).

This variable was tested in the present paper, being expressed by the number of domestic departures in the year 2001 from each airport, CGH and GRU. International flights (available at GRU) were not considered because CGH has only been serving domestic destinations lately. The fact that the traffic volumes considered at the studied airports are from year 2000, in function of availability and updating, doesn't spoil in any sense the data collection of this variable since the questions treated are from different nature.

5.4. Overall considerations on the models

The value of the variables was input directly in the decision function, without any mathematical modification, enabling the immediate analysis of the tradeoffs between the variables pertaining to the same model (what happened in the models with 2 or 3 variables). To begin with, 77 models were calibrated. Variables belonging to the same category didn't take part of the same model.

Table 3 exemplifies the decision functions of a fictitious passenger that flew from GRU to BSB, departing in the morning peak of February 25th, 2002, having left the zone

called "Penha" (in Sao Paulo city) in the day of his travel. Admit that this passenger departed twice from GRU and once from CGH during the year 2001. For one model built with three variables such as AT, DPF and EXP, equations (8) and (9) are obtained.

Table 3: Variables AT, DPF and EXP for a fictitious passenger

	AT (min)	DPF	EXP
GRU	29.9	21	2
CGH	53.2	49	1

$$1 = \frac{\exp(\alpha_1.29.9 + \alpha_2.21 + \alpha_3.2)}{[\exp(\alpha_1.29.9 + \alpha_2.21 + \alpha_3.2) + \exp(\alpha_1.53.2 + \alpha_2.49 + \alpha_3.1)]} \quad (8)$$

$$0 = \frac{\exp(\alpha_1.53.2 + \alpha_2.49 + \alpha_3.1)}{[\exp(\alpha_1.29.9 + \alpha_2.21 + \alpha_3.2) + \exp(\alpha_1.53.2 + \alpha_2.49 + \alpha_3.1)]} \quad (9)$$

6. Results

6.1. Models considering only one explanatory variable

Fifteen models belonging to this category were built, using one by one the 15 variables selected in the previous section of this paper. The comparison among these models bring out the variable with best explanatory power on the airport choice in Sao Paulo Metropolitan Area. Table 4 presents the calibration results of these models.

The signals for the coefficients were those expected: negative for ACCESS and positive for FREQUENCY and EXPERIENCE. Indeed the increase on access distance and time are undesired, whereas the supply of flights and the experience a passenger has with an airport are desired and their increase propels the airport choice.

The t-Student statistics were satisfactory, presenting modulus higher than 2, whereas the null p-value in all the cases also indicated satisfactory participation of the variables in the models. The calibration of the models with one variable revealed R^2 values among 0.01041 and 0.17978. The associability extremes with the dependent variable were the model considering EXP (best associability) and the model considering IPF (worst associability). Since the fraction of concordant pairs in all the cases fell between 51% and 61% of the data, the adjustments were regarded as of medium quality.

IPF presented low explanatory power on the airport choice, probably because an indirect flight (enhancing stops or connections) is extremely undesired whenever direct flight frequencies are available to the chosen destination.

Table 4: Models with only 1 explanatory variable

Model	Variable	R^2	Coefficient	t-Student	p-value	Fraction of concordant pairs
1	AD	0.04941	-0.0185	-11.427	0	0.54
2	AT	0.05931	-0.0140	-12.210	0	0.54
3	DDPF	0.12613	+0.1951	16.123	0	0.59
4	DDF	0.11768	+0.0305	14.921	0	0.58
5	DPF	0.13269	+0.0336	16.593	0	0.59
6	DWF	0.12468	+0.0054	15.336	0	0.58
7	IDPF	0.01133	+0.0613	6.155	0	0.51
8	IDF	0.02146	+0.0146	7.945	0	0.52
9	IPF	0.01041	+0.0099	5.959	0	0.51
10	IWF	0.01878	+0.0024	7.525	0	0.52
11	TDPF	0.07890	+0.0883	13.809	0	0.55
12	TDF	0.08634	+0.0154	14.055	0	0.56
13	TPF	0.08235	+0.0154	14.048	0	0.56
14	TWF	0.09081	+0.0028	14.311	0	0.56
15	EXP	0.17978	+0.1023	14.780	0	0.61

Yet EXP was the variable exhibiting the best explanatory power on the airport choice in Sao Paulo Metropolitan Area, probably because the more a passenger travels, the more used he gets to the tradeoffs pertaining to an airport choice, as well as he becomes aware of these tradeoffs, creating a consistent structure of terminal choice and accumulating more experience of departure from one of the airports.

Among the variables of frequency, direct flight frequencies in the period of departure (DPF) showed best explanatory power on the airport choice in Sao Paulo Metropolitan Area. The ranking of the variables of frequency was notorious: the best adjustments fell among the direct frequencies, followed by the total frequencies and lastly were observed the indirect frequencies.

From the point of view of a connection or a stop on the way to the destination, the supply of direct flights was better explained the airport choice. It is evident that delays produced by a connection or a stop are undesired due to the loss of time, since the rapidity is the main advantage of choosing the air mode. Therefore, as the total frequencies enhance the direct ones, total frequencies occupied the second place in the ranking, better explaining the airport choice than the purely indirect flight frequencies.

Among the direct flight frequencies, ranging from the one which best explains the airport choice to the one that has the lowest explanatory power, it was found: DPF, DDPF, DWF and DDF. The difference among the quality of the adjustment found was not significant, albeit perceivable. It was found that passengers are more prone to shift their departure date than their departure period of the day. Moreover, the departure period of the day (represented by DPF) was more significant than the day and period of departure itself (represented by DDPF).

A possible explanation for the better adjustment of DPF in comparison to DDF is that passengers may show availability along the week to make their trips, but appointments with which they fulfill their schedule along the day may be regarded as a priority. For instance, on the one hand consider a businessman that must depart in the early morning from Sao Paulo to participate at a meeting at 10 AM in Belo Horizonte. On the other hand there are plural options of days along the week when this meeting could be held. As another example consider a worker living in Sao Paulo that decides to spend one week in the seaside of Rio de Janeiro beaches. Vary the period of departure along the day may mean poor scheduling of his trip, whereas there wouldn't differ much if his trip were scheduled in the first or in the second week of his one month vacation.

Among the indirect frequencies, ranging from the one which best explains the airport choice to the one that has the lowest explanatory power, it was found: IDF, IWF, IDPF and IPF. Also in this group the difference was not that big. On the other hand the frequencies along the day were more significant probably because when the passenger faces scarcity of direct flight frequencies during the airport choice process, he becomes careless about shifting his flight schedule along the day since he will undoubtedly affront the vicissitudes of a delay caused by a connection or stop on his way to the destination.

Among the total frequencies, ranging from the one which best explains the airport choice to the one that has the lowest explanatory power, it was found: TWF, TDF, TPF e TDPF. Also in this group the difference was not that big. Maybe the weekly frequencies assumed the leadership in the airport choice process because of the importance of the multitude of options when total frequencies are analyzed, i.e., when the passenger doesn't have any guarantee that he will fly with or without a connection or stop.

Regarding the variables of ground accessibility, access time was most significant one, possibly because the passengers not only prefer the closest airport to the trip origin but also this proximity must be expressed much more in terms of time economy than in distance economy.

6.2.Models with two explanatory variables

From this category, 38 models were built, considering all combinations of two variables among those selected in the previous section of this paper, paying attention not to input variables of the same type in one model. The analysis of these models enables the evaluation of the tradeoffs passengers face between the best choice variables at their airport selection. Table 5 shows the calibration results of the models with higher R^2.

In most models with two variables, the signals of the coefficients were those expected: negative for ACCESS and positive for FREQUENCY and EXPERIENCE. However, the signals of IDPF and IPF were negative in the models calibrated with AD and EXP. Since the modulus of the t-Student statistics was lower than 2 and the p-value of the variables of indirect flight frequencies was high in many cases, the inclusion of indirect frequencies showed itself undesirable to represent the airport choice in certain specifications of the decision function.

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Table 5: Best models considering 2 variables (higher R^2)

Model	Variable 1	Variable 2	R^2	Coefficient 1 (t-Student)	Coefficient 2 (t-Student)	Fraction of concordant pairs
1	AT	DPF	0.15449	-0.0092 (-7.459)	+0.0301 (14.350)	0.60
2	AT	EXP	0.19490	-0.0079 (-6.249)	+0.0932 (13.454)	0.62
3	DPF	EXP	0.23410	+0.0240 (11.226)	+0.0820 (11.932)	0.65

The calibrations of the models considering two variables revealed R^2 values between 0.04942 and 0.23410. The associability extremes with the dependent variable were the model considering EXP and DPF (best associability) and the model considering AD and IWF (worst associability). Since the fraction of concordant pairs in all the cases fell between 54% and 65% of the data, the adjustments were regarded as medium quality.

As expected, a model considering one variable of indirect flight frequencies was the least adjusted to the data, since the passengers obviously prefer direct and total flight frequencies, as exposed before. Yet the access distance is less preferred than the access time, since the time economy in intrinsic to the air transportation as a travel mode, then the time economy during the access to the terminal is also more searched than a shorter distance.

The experience once again appeared in the best model. A possible explanation is that the experience with airport results from a detailed trip choice process, then the airport choice for the trip that took place during the day of the interviews should be connected to the passenger experience with that terminal in previous occasions. Besides experience, DPF reflected that passengers probably exercise their right to consult each airport's flight schedules well in advance of the ticket emission, thus preferring direct flights that bring about higher utility than the delays of indirect flights

The models with two variables have been classified in three groups: a)those considering variables of access and frequency; b)those with variables of access and experience and c)those with variables of frequency and experience. Among these three configurations, the last one provided the most adjusted model to the database (R^2 = 0.23410), involving the variables DPF and EXP. Thus once again experience was found to contribute to the formation of a consistent airport choice structure. Moreover, it was noticed again that passengers prefer the direct flight frequencies.

As well as observed in the models with one variable, the models with two variables considering one variable of indirect flight frequencies presented the lowest R^2 value. Once again was shown the fact that connections and stops on the way to the destination are undesired in comparison with total and direct flight frequencies.

6.3.Models of three explanatory variables

Among the models with three variables, 24 models have been tested, using all combinations of three variables among the 15 variables selected in the previous section, paying attention not to include in the same model variables of the same type. Therefore, for instance, TWF and DWF were not tested in the same model specification because both of them are variables of flight frequencies.

In the same way as the models with two variables, the models considering three variables enable the evaluation of the tradeoffs passengers face between the best choice variables at their airport selection. The best model considered access time to the airport, direct flight frequencies in the period of departure and passenger experience with analyzed airports. This model was selected for further analysis of passenger market segments. The result of its calibration is shown in table 6.

Tabela 6: Model with three explanatory variables that presented the highest R^2

Model	Variables			R^2	Coefficients (t-Student)			Fraction of concordant pairs
	1	2	3		1	2	3	
1	AT	DPF	EXP	0.24011	-0.0052 (-3.975)	+0.0226 (10.346)	+0.0775 (11.248)	0.65

It was also verified that in the models with three variables the signals of the coefficients were usually those expected: negative for access and positive for frequencies and experience. In the cases which this didn't occur, the modulus of the t-Student statistics was low, around 2, and the p-value of their variables differed from zero, indicating that the inclusion of the variables related to these coefficients are undesirable to represent the airport choice in the considered specifications of the decision function.

Because the fraction of concordant pairs in all the cases fell between 62% and 65% of the data, the adjustments were considered of medium quality.

The models with three variables can be classified by two basic criteria: a)by the variable of access and b)by the variable of flight frequencies. The variable of experience pertained to all the three-variable-models.

Grouping the models with three variables by the variable of access, two groups are formed: those which consider AT and those which consider AD. The quality measure indexes of the adjustment of the models with AD were lower than those which considered AT, probably because time economy during the access to the terminal is also more searched than a shorter distance.

Considering the frequency criteria, the models with three variables were divided into three groups: a) those which considered direct flight frequencies; b) those which considered indirect flight frequencies and c) those which considered total (direct plus indirect) flight frequencies. Once again the measures of goodness of fit were lower

whenever indirect flight frequencies were taken into account, whereas the measures of goodness of fit were higher in the case with direct flight frequencies.

The calibrations of the models with three variables revealed R^2 values among 0.18634 and 0.24011. In two extremes of associability with the dependent variable, the variable EXP has taken place, and EXP has already proved to play a significant role in the airport choice. What has differentiated these models was the presence of AT and DPF constituting the highest associability and AD and IDF constituting the lowest associability. Once again an indirect flight frequency (with connection or stop) has little influenced the airport choice in comparison to those direct and total. Moreover, the variable AD is less preferred than AT, as said previously, the time economy is intrinsic to the air transport mode choice, thus the time economy plays a more important role on the airport choice than economy in terms of distance.

To analyze the tradeoff between the variables of the best model, it is verified that the coefficient of DPF is 4.35 times higher in modulus than that of AT. Therefore through this model it is inferred that passengers put up with taking about further 4 minutes to one airport in exchange of each direct flight frequency in the period of departure this airport offers to the desired destination. For distant zones from one airport, where the access time exceeds one hour in certain periods of the day, 4 minutes further in the access wouldn't matter much, and also an increase of one direct flight frequency would be extremely beneficial in the case of a destination poorly supplied by direct flights. On the other hand for close zones to one airport, further 4 minutes in the access do bring a slight inconvenience, and also an increase of one direct flight frequency wouldn't mean a significant improvement in the case of the most popular destinations.

Moreover, the coefficient of EXP is 14.90 times greater in modulus than AT. Therefore through this model it is inferred that passengers put up with taking further 15 minutes to one airport for each experience of departure he had for domestic flights using this airport in the year before the interview took place.

Last but not least, the coefficient of EXP is 3.43 times higher in modulus that that of DPF. Therefore through this model it is inferred that for each experience with domestic flights a passenger had in the previous year with one airport, he puts up with the absence of supply of three flight frequencies to the desired destination in that airport.

A practical and interesting illustration of what this model reveals is the calculation of the percentage distribution between airports, of the passengers without any experience in the year 2001 with GRU and CGH airports. In this case, even considering a model of three variables, the airport choice is based on the tradeoff between only AT and DPF. Suppose for exemplifying reasons that these passengers leave zone 55 (Mooca in Sao Paulo), traveling in the morning peak of February 19th, 2002 to (destination BSB). Table 7 shows the variables related to their choice.

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Table 7: Variables AT, DPF e EXP for ficticious passengers.

I	Airport	AT	DPF	EXP
1	GRU	32.4	21	0
2	CGH	31.9	42	0

$\exp(U_1) = \exp(-0.0052*32.4 + 0.0226*21 + 0.0775*0) = \exp(0.3061) = 1.3581$
$\exp(U_2) = \exp(-0.0052*31.9 + 0.0226*42 + 0.0775*0) = \exp(0.7833) = 2.1887$
$\Sigma\exp(U_i) = 3.5468$
$p_1 = \exp(U_1)/\Sigma\exp(U_i) = 1.3581 / 3.5468 = 38\%$
$p_2 = \exp(U_2)/\Sigma\exp(U_i) = 2.1887 / 3.5468 = 62\%$

6.4.Analysis of the variables of the chosen model in terms of passenger market segments

Having found the model with higher R^2, which considered the variables access time, direct flight frequencies in the period of departure and experience, the interviewed passengers were segmented by airport of departure and flight range, as Table 8 shows.

Table 8: Calibrations of the model with greater R^2 across some market segments

Market segments	AT	DPF	EXP
Passengers departing from GRU	0.0242	– 0.0064	0.0248
Passengers departing from CGH	– 0.0752	0.0587	0.1324
Passengers in shorter-haul flights	– 0.0184	0.0075·	0.1042
Passengers in longer-haul flights	– 0.0035	0.0444	0.0665

The signals of the coefficients of AT and DPF are not counterintuitive in the case of GRU (the expected passenger behavior is to select the closest airport to the trip origin and the airport with a superior supply of direct flight frequencies to the desired destination, as far as possible), while at CGH the signals were not only the expected ones but also their values were higher than those encountered for sample prior to segmentation.

Regarding the access, the positive signal of AT at GRU indicates that the passengers that have chosen GRU for their trips didn't show priority for the variable of access time, since GRU is the farthest of the two analyzed airports from the center that generates air transport demand in the Sao Paulo Metropolitan Area. This is verified by the random sample collected: among the zones enhancing 50 or more interviewees, only one zone is closer to GRU in terms of access time, whereas the 13 other zones with more than 50 interviewees are closer to CGH.

Meanwhile a possible explanation for the correct negative signal and high value of the coefficient of AT in CGH is that the center where air transport demand is generated lies closer to CGH than to GRU.

Regarding airlines' level of service at the competing airports, the high value of DPF in CGH in comparison to the sample as a whole is justified by the observation of only domestic flights departing from CGH, whereas GRU's runway is shared by domestic and in large scale international flights. In the case of some destinations like Rio de Janeiro and

Belo Horizonte, the choice of CGH as an airport of departure is by far related to the desire to land respectively at SDU and PLU, whereas the departures to their respective competing airports GIG and CNF, whose demands are comparatively smaller, are somewhat concentrated at GRU.

Finally the experience is a more important factor in CGH than in GRU. Very many CGH passengers have already structured their airport choice process, and repeat this option as far as possible (whenever there is flight supply to the desired destination).

The coefficient of the variable of access time was presented a higher modulus for passengers in short-haul flights. More importance on access time is expected for this market segment, which searches the closest airport, since access time means a larger part of the door-to-door time of the trip for those flying shorter distances.

Yet, the coefficient of DPF was higher for passengers in long-haul flights. It is expected that these passengers place more importance on airline level of service, since they are going to remain a longer time inside the aircraft. Besides, it is more common for long-haul flights to include a connection or stop (and thus they are more time-consuming) than for short-haul ones. Therefore long-haul flight passengers search more enthusiastically an airport that offers direct flight frequencies.

7.Conclusions and recommendations

Aiming at analyzing the airport choice made by the passengers in the Sao Paulo Metropolitan Area, conditional LOGIT model was used as a modeling tool.

Decision functions for each passenger were built, one for the chosen airport and another for the airport not chosen.

Several specifications for the decision function were tested. These specifications enhanced independent variables pertaining to 3 groups: a)variables related to the airport access; b)variables related to the airlines' level of service in the airports; c)one variable accounting for the passenger's experience with the airports in the region.

The decision functions were built considering one, two or three of the variables described above, taking care not to mix variables of the same group in one model. The specification that produced the model most adjusted to the data (evaluated in terms of higher R^2) enhanced the following variables: access time, direct flight frequencies in the period of departure and passenger's experience with the airports in the studied region.

Using the variables obtained from the best model, the airport choice was analyzed in terms of a passenger market segment by airport of departure and flight range.

From the analysis of the results achieved with the data collected for this work and for the region treated in this paper, it is possible to affirm that, generally:

1. The experience a passenger has with an airport of departure is the factor that can better explain the airport choice;

2. The access time to an airport better explains the airport choice than the access distance;

3. The direct flight frequencies exhibit better explanatory power on the airport choice than those total and the latter on those indirect;

4. The choice of GRU is not well explained by access time economy savings and by an increase in the supply of direct flight frequencies in the period of departure to the desired destination, contrarily to the choice of CGH, which is;

5. The access time is more important to those passengers in short-haul flights, whereas the supply of direct flight frequencies in the period of departure is more important to those passengers flying longer distances;

The recommendations are addressed to each group connected directly or indirectly with the air transport activity. These recommendations were made up from this work, being restricted to its characteristics, such as seasonality of the interviews along the year, the existing politic and economic scenario, delimitation of the trip origin region, studied destinations, model specifications, variables employed in the modeling, and so on. It is recognized that to put into practice any of these recommendations, it is necessary caution and validation of the conclusions of this work through periodic evaluations (studies) of the airport choice in Sao Paulo Metropolitan Area.

In order to satisfy the level of importance placed by air passengers on the access time, when the market is segmented by flight duration, this work advises the Air Transportation Authority to schedule short-haul flights at CGH, close to the center of origin of the air transport demand in Sao Paulo Metropolitan Area. In this way, long-haul flights should therefore be scheduled at GRU.

Meanwhile, to establish a perimeter rule in the air transport regional system in Sao Paulo Metropolitan Area, besides this passenger market analysis, it is also necessary to conduct a technical evaluation of the landside and airside capacities of the airports where the departures and connections would be scheduled (the latter may involve airports outside the region), as well as an economic evaluation from the standpoint of the yield management in case a perimeter rule is to be adopted.

For the airport managers, it is recommended to reserve areas at their terminals for business, social and cultural events, which should be advertised countrywide, attracting residents and visitors (non-residents). While the residents are potential passengers, the visitors enhance their experience with the airport where the event is held, factor revealed in this work to be best explaining the airport choice in Sao Paulo Metropolitan Area.

Since an expressive amount of passengers either declared having chosen their airport of departure not being aware of the supply of flights to their desired destination from a competing airport located in the same metropolitan area or even someone else (possibly somebody from their workplace or a travel agent) made their airport choice for them, therefore the events made available in a competing airport is a potential policy to broaden the participants minds in terms of considering this airport as an alternative of departure for their following flights.

This work showed that the choice of GRU is not base on the rationale of access time savings and increase in the supply of direct flight frequencies in the period of departure to the desired destination. The rationale of choosing GRU is based on the passenger experience with the airports in Sao Paulo Metropolitan. Thus, it is recommended that the airlines offer non-aeronautical advantages to make a passenger choose GRU as an airport of departure for the analyzed domestic destinations. For instance, these advantages may be related to the provision of either ground transportation to access GRU or a parking lot in the vicinity of GRU.

Since the experience was found to be the factor best explaining the airport choice in Sao Paulo Metropolitan Area, this work points out that the airlines can increase their aircraft occupancy by concentrating marketing efforts on those passengers who place more importance on their experience with the two airports: those who depart from CGH and those who fly shorter distances.

Because it was found that the choice of CGH is motivated by the proximity in terms of the variable of access time, while the choice of GRU is not, this work points out for the urban transportation planners that an improvement on the access such as connecting GRU to the subway system existing in the city of Sao Paulo, is likely to enhance the choice of CGH in case a station is included in the city of Guarulhos, rather than enhance the choice of GRU by the passengers living in the city of Sao Paulo (for the competing domestic flights).

8.Future work

Three alternatives are proposed to extend the research on airport choice in Sao Paulo Metropolitan Area:

a)Capturing possible changes in passenger choice behavior in Sao Paulo Metropolitan Area in different months of the year;

b)Applying the very same principles employed in this paper to other brazilian multiple airport regions;

c) Applying the very same principles employed in this paper to other air transport related choices in Sao Paulo Metropolitan Area, such as airline choice for domestic and international flights and the choice of interurban transportation mode, in which the air mode competes against the ground mode for several destinations.

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AN ANALYSIS OF DELAY AND TRAVEL TIMES AT SÃO PAULO INT'L AIRPORT (AISP/GRU): PLANNING BASED ON SIMULATION MODEL

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ABSTRACT
The occurrence of flight delays in Brazil, mostly verified at the ground (airfield), is responsible for serious disruptions at the airport level but also for the unchaining of problems in all the airport system, affecting also the airspace.

The present study develops an analysis of delay and travel times at São Paulo International Airport / Guarulhos (AISP/GRU) airfield based on simulation model.

Different airport physical and operational scenarios had been analyzed by means of simulation. SIMMOD Plus! 4.0, the computational tool developed to represent aircraft operation in the airspace and airside of airports, was used to perform these analysis.

The study was mainly focused on aircraft operations on ground, at the airport runway, taxi-lanes and aprons. The visualization of the operations with increasing demand facilitated the analyses.

The results generated in this work certify the viability of the methodology, they also indicated the solutions capable to solve the delay problem by travel time analysis, thus diminishing the costs for users mainly airport authority. It also indicated alternatives for airport operations, assisting the decision-making process and in the appropriate timing of the proposed changes in the existing infrastructure.

Key Words: Airports, Capacity, Simulation, Demand, and Delays

1. INTRODUCTION
An increasing number of users of air transportation in the whole world can be observed along the years (ICAO, 1999). Although the attacks in New York (United States) on September 11th, 2001 have generated conservation (in some cases fall) in these numbers, the whole aviation sector expects the retaking of the growth of indexes in a short term.

In spite of the apparent pause in the growth, traffic jams in the airspace and airports continues to happen and causes frequent delays, harming all participants of the airport system. The search for solutions mobilizes from airlines to air traffic control organizations.

To have an idea of the losses, in November 2000, the airport operations in Brazil generated losses in a Brazilian airline that reached the value of US$ 1 million (Targa, 2001). These losses,

generated in concentrated way due to delays in the flights, most of the time they were verified in the ground (airports), unchaining problems in every system, reaching even the airspace.

Due to the observation of the problem, analyses were made in possible operational scenarios in the International Airport of São Paulo / Guarulhos (AISP/GRU), main airport of South America in passengers' movement, based on a simulation model attesting its viability as a methodology in airport planning systems, varying the growth of the demand expressed for the aircraft's movement.

For this purpose it was used, the computational tool SIMMOD. A tool developed by the Federal Aviation Administration – FAA, civil aviation authority in the United States, capable to show through simulation the operation in the airspace and airside of airports, producing results that allow the analysis of such systems.

This methodology is consecrated in the field "airports operation analysis", with several works already implemented in the world (TRANSSOLUTIONS, 2000; Delcaire, B., Feron, E., 1997; Trani, A. A., Wing-Ho, F., 1997), including Brazil (Pereira et al., 2000; Barros, 1994).

The models in SIMMOD are discrete, dynamic and stochastic. SIMMOD represents airports and airspace system as a series of nodes connected by links. A node is defined as the position in a system of coordinates where the simulation evaluates the location of an aircraft with regard to other aircrafts from the system. All events happen according to the existent characteristics in the construction of such links.

The operation of the models developed in the tool is described in the Figure 1, being part of their events, attributes and entities considered as input data. In the tool there is also a great amount of information related to the operational performance of the aircrafts that can be classified as entities in the system besides an algorithm well built as for the airport operations.

2. JUSTIFICATION

The São Paulo Terminal Area, where AISP/GRU is inserted, is being reason for concerns from planners, administrators and operators of the airports, due to the "bottlenecks" existent in air operational procedures generating a traffic jam situation and problems as for its viability on the ground or in the airspace.

Due to the complexity of the problem, the users of the system are recurring to computer science more frequently, which subsidizes the development of new capacity analysis methodologies, where the simulation has its outstanding status. As main justification for the use of such a methodology, it is verified that the modeling using simulation techniques became quite efficient in the resolution of complex problems, possessing a very low cost if compared to the accomplishment of an experience with the real system. In the context of the air transportation, SIMMOD has been showing quite satisfactory results.

However the modeling of the object in study, its identification and the search for the best guidelines in the present researches were not tasks easy to be accomplished, once the main analyses were resulting of several technical visits to the control tower of the airport, exhausting dialogues with the responsible for the traffic in the ground (airside of the airport), full learning of the tool SIMMOD and, above all, the understanding and construction of operational scenarios for the new terminal of passengers (TPS - 3) and of the new track of landings and takeoffs. Their strategy of operation is still not known.

For the construction of the scenarios it was considered the increases in the demand, forming an alliance of this criterion with the changes of the physical layout (improvement of the infrastructure), a new runway for landings and takeoffs, and implantation of a new terminal of passengers (TPS - 3). The sensibility analysis were made confronting the demand increase in the flights against the value of delays and displacement times accomplished in the operations of landings and takeoffs called as travel times, measuring all the influence of the improvement of the airport infrastructure in the simulated alternatives.

The results will be able to assist the decision-making process and in the appropriate timing of the proposed changes in the existing infrastructure.

3. AIRPORT SYSTEM CAPACITY
The airport capacity is defined as "the maximum number of operations of aircrafts, established for a certain aerodrome, for specific periods, supported by the airport infrastructure" (Siewerdt, 2001). Starting from this concept the decisions taken in relation to the development of the infrastructure are decisive for the visualization of the complete increase of system capacity.

However, the capacity is also limited by the weakest factor of the system where it is inserted, since the airspace capacity, or a new runway of landings and takeoffs, or apron area, or terminal of passengers, or simply the accessibility of the passengers to the terminal.

According this information it can be noticed how big is the problem of the increase in the capacity of airport systems. As consequence, it is observed a necessity of searching solutions, for the complete system - airspace until the access to the terminal - or simply for each factor that involves it.

4. SÃO PAULO INTERNATIONAL AIRPORT (AISP/GRU)
The biggest airport complex in Brazil, AISP/GRU was conceived originally to assist the metropolitan area of São Paulo to the demand of domestic flights that used the Congonhas airport, except for the shuttle service between Rio de Janeiro - São Paulo, as well as the international flights related with the integral countries of the South Cone, also serving as an alternative for the Campinas airport.

Although it has been planned to serve a certain scenario and objective, the administration authority of the Airport couldn't maintain the initial idea, making necessary the implantation of new strategies capable to absorb the unpredicted demand.

The AISP/GRU, the Brazil's biggest "gate of entrance", is responsible for more than 70% of the international passengers (origin/destiny) processed. It concentrates, in Brazil, the largest traffic of regular passengers, the first relative placement to the total volume of freight and postal transport, besides the great movement of aircrafts of total regular traffic (INFRAERO, 2000).

4.1. New facilities

Looking forward to solve these problems that are happening, mainly in the part of infrastructure of AISP/GRU, Brazilian Airports Infrastructure Company - INFRAERO - is proposing as alternatives, the construction of a new terminal of passengers (TPS - 3), and another runway of landings and takeoffs, absorbing simultaneous operations of the aircrafts, identified as the bounding factor for the increase of system capacity.

5. METHODOLOGY - THE MODELS CONCEPTION

Starting from the definition of the problem to be studied, the first step of the methodology consists of listing the data and necessary information for the conception of the models and the means to obtain them.

For that, basically, the model demands that are detailed the inherent aspects to the demand, operation of the aircrafts (Brazilian Ministry of Aeronautics, 1987) and geometric configuration of the airport infrastructure and of the terminal airspace (Brazilian Ministry of Aeronautics, 1993) existent today. The construction of the model is a computational work in which all this information is inserted in SIMMOD (Pereira et al., 2001).

The last phase for conclusion of the basic model consists of the validation and verification of it. Some metrics are generated and selected by the simulation for comparison with real data of the airport operation, verifying if the obtained deviations are within the maximum limits of tolerance stipulated.

The conception of the models followed the plans of enlargement of the infrastructure of AISP/GRU, which have been proposed by INFRAERO.

In the study now presented were conceived 6 models, relative to two new configurations, besides the simulation of the current situation. Each one of the configurations was simulated with the present demand (registered on March of 2000) and with increments that vary from 2% to 30% on the current demand, totaling 15 increment values. The results for each one of them were converted in delays (cost), and confronted against the growth of the demand. The comparative analysis was generated from these results.

The demand on March 2000 had in its peak day 555 operations; while in February 2002 the number of operations in the peak day was 534 operations (INFRAERO, 2002). In other words, on these 2 years, the change was not significant; there was conservation in the numbers. These times were originated by facts as the attacks in New York on September 11, 2001, besides the exit of

the airline Transbrasil that paralyzed a great range of the market with domestic and international flights.

The 6 models built and simulated with the tool SIMMOD were:
· M1: Current situation;
· M2: Hypothesis with the addition of the third runway of landings and takeoffs;
· M3: Hypothesis with the addition of the third runway and third terminal - first operational strategy;
· M4: Hypothesis with the addition of the third runway and third terminal - second operational strategy;
· M5: Hypothesis with the addition of the third terminal - first operational strategy;
· M6: Hypothesis with the addition of the third terminal - second operational strategy

Due to the inexistence of information about the behavior and the operation of the new terminal of passengers, in development, in this work two options of operational strategies were adopted.

5.1. Current Situation Model
The model built to show the current situation of AISP/GRU, followed the data from AIP (Brazilian Aeronautical Command, 2000). It has two parallel runways of landings and takeoffs, being one with 3000m of length (09R/27L) and the other with 3700m (09L/27R). The separation between the axes of the runways is 375m. In the direction 09, the thresholds are 500m staggered, runway 09R is used primarily for the operations of landings (85%) (IAC, 1999), and runway 09L is used most of the time for takeoff operations.

The staggered runway configuration results an effective separation among runways of 485m (addition of 30m for each 150m of staggering). However, the minimum separation suggested by ICAO is of 760m to segregated dependents operations of landings and takeoffs in parallel runways, in visual flight rules (Barros apud Nagid, 1994). Though, runways with separation larger than 300m can operate in the system dual lane, in other words, authorized takeoffs when the aircraft touch the ground. Such is the procedure adopted by AISP/GRU to optimize the use of the existent infrastructure.

The airport has 2 terminal building (finger concept), with eleven parking positions each one. Only three positions at the finger extremity can receive aircraft larger than Boeing 767. This fact is due the initial proposal in which the airport would assist only South America flights. However, INFRAERO are already modifying the structure of the aircrafts parking positions in the terminals and should conclude this stage until the end of 2003.

The 2 terminals buildings have a planned capacity to receive, each one, up to 7.5 million PAX/year.

5.2. Third Runway Model
The development of this model was directly linked to the new project that INFRAERO is developing.

The master plan of the airport established a third runway with 2025m of extension. However to implement that, it was adopted its construction inside existent patrimonial area, under the responsibility of INFRAERO as basic premise. According this, the solution was to locate the runway to 1462m from the runway 09L/27R axis, reducing the original length for 1800m.

The most appropriate position for the implantation of the third runway inside of the patrimonial limits, it was then to 1462m of the axis of the current runway 09L/27R, resulting in the dimensions of 1800m X 45m, could be enlarged for the 2025m, predicted in the master plan, by incorporation of new areas to the airport.

IAC (Civil Aviation Institute) in the report of viability of operation of the third runway of landings and takeoffs (IAC, 1999) has verified that a runway of 1800m would allow the landing and takeoff, in most of the cases with 100% of the acceptable maximum weights. Besides, as for the positioning of the runway of parallel taxi-lanes, the criterion of FAA was adopted (Federal Aviation Administration), that it establishes a removal of 120m of the axis of the new runway, compatible with aircrafts with wingspans minor or equal to the one of the Group IV (up to 52m of wingspan), that reaches Fokker 100, Boeing 737, 767, and others. The report attests that about 80% of the programmed operations to the airport can be accomplished in the future third runway, excluding only the aircrafts that accomplish international flights.

A factor that harms the operation of the third runway lives in the accessibility of the aircrafts for the accomplishment of the landing operations and takeoffs. Starting from that consideration the need was verified of doing an analysis among the values of delay and travel times.

With the entrance of the operation of the third runway, IAC (IAC, 1999) in the same study it was presented the configuration of the new mix of aircrafts to the airport together with the percentile of use of the runways as for the operation (Table 1) that was used in the conception of the model.

5.3. New Terminal of Passengers (TPS-3) Model
As well as the development of the previous model, the implantation of a new terminal of passengers in the model considered the premises of the project bid by INFRAERO, approximating to the reality the future operations.

Starting from the knowledge of demand studies accomplished by IAC (Brazilian Ministry of Aeronautics, 1999), where it was pointed for the year 2017 a movement of passengers in the order of 39 million PAX/year, INFRAERO bid in 1996 the project for the construction of the third terminal. Their main characteristics were (INFRAERO, 2000):

· Capacity for 12 million PAX/year;
· Architectural concept should accommodate the largest possible number of aircrafts parking on nose in, with two positions dedicated to NLA's (new large aircraft) and the minimum of seven positions for aircrafts type Boeing 747-400;

· Expansion Capability, making possible the implantation of the fourth terminal with identical dimensions;
· The access circulation to the bridges was divided in two levels to separate passengers' departure and arrival flows;
· Mix of stands for aircrafts of great and medium loads;
· Semi-automated System of dockages of aircrafts.
· Construction of one more remote parking area for the aircrafts of great, medium and small load, access the third runway and still a small linear terminal, that will absorb part of the domestic traffic.

5.3.1. Operational strategies in the Third Passengers Terminal (TPS-3)
As mentioned previously, the operation of the new terminal of passengers (TPS-3) of AISP/GRU is an unknown that reaches all of the users of the system.

Once it is not the objective of the present work to point the best ways to obtain the best operation, it was decided to come up with 2 propositions of operations and to submit them to the simulation.

The 2 propositions were based in:

· Percentile Division of the operations for each airline;
· Alliances among the airlines;
· Apron Capacity - size of the aircraft and their restrictions;
- Flight Plan Characteristics;
· Operations balance within the 3 terminals.

The way 2 operational scenarios were generated where there was a proportionality to the capacity projected for the passengers' processing, TPS-1 and TPS-2 with 7.5 million PAX/year, representing 27.8% each of the passengers' demand and TPS-3 with 12 million PAX/year, representing 44.4% (Table 2). It is worth to remind that the scenarios were elaborated according to demand of March 2000 (INFRAERO, 2000).

6. DEMAND
Looking for to evaluate the study object better, and to produce results to generate significant analyses as for the capacity on the airport airside, it was verified that the variation of the demand associated to the simulations in the models would consist in the very important step.

The study "Detailed Demand Analysis of Brazilian Airports" (Brazilian Ministry of Aeronautics, 1999) indicated that a 30% demand growth on the number of operations was expected in the AISP/GRU in a 5 year-horizon. The adoption of a range of increasing demand values was influenced by the lack of an updated forecast model after the countless problems caused in the world and Brazilian aviation by the attacks in the USA, that caused the observed break and decrease of flights.

Therefore, models representing 16 demand levels, ranging from 0% to 30% demand increment, were simulated and the for each one the level of traffic and the respective delays and travel times were obtained.

The results allowed identifying the potential behavior of the average delay and average travel time, evidencing, this way, the appropriate instant to intervene in the installed infrastructure.

7. RESULTS AND ANALYSES

To generate results with statistical significance, although the experience suggests 5 iterations as enough to ensure statistically valid results (TRANSSOLUTIONS, 2000), 20 iterations of each analyzed model were performed.

After executing the simulation, the first concern was that regarding the validation of the model, turning it capable to accomplish the other proposed analyses. The validation stage was accomplished starting from the comparison of the results of the simulated system with the real system, testing logically and numerical the model.

The validation followed the criteria:

· Representative day = peak day of the data base supplied (March of 2000)
· Total Period used in the simulation = 1 day of airport operations = complete cycle
· Validation Process and verification = comparison of the generated results (Figure 2)

Besides the number of operations, the process of validation of the model of the current situation consisted of the close verification of the input data from the report of the International Consultancy MITRE Co. (MITRE, 2001) contracted by the Civil Aviation Authority (DAC). In this report, MITRE Co. mentions that the maximum capacity is between 46 and 49 operations, varying that number according to the operation type, departure or arrival. The model developed in SIMMOD obeyed exactly to these numbers, arriving in the maximum number of 50 operations with an increase in the demand of 30% reaching its capacity limit.

In Figure 2 the adaptation of the "flotation" of the number of operations was observed, besides with the proximity of the "peaks" and "valleys" operational between the real values and the simulated model.

Other metric verified was that related to the number of aircrafts in the takeoff line that coincided with the numbers of INFRAERO. In the peak hour, these values reached 9 aircrafts in the waiting line on the ground, both in the developed model and in the real operation.

7.1. Analysis of the Results

The analysis of the simulated operational models is linked to the demand and offer of the system, besides the installed capacity of the airport.

Observing Figure 3 it is noticed the influence of the third runway of landings and takeoffs firstly in the decrease of delays. It is clear the existence of the division, among the models, in 2 groups with seemed characteristics as for the variation in the evolution of the demand. They are differentiated amongst themselves just by the inclusion of the third runway in their scenarios.

It is also demonstrated in the same Figure 3, that the percentile growth of the delays doesn't depend a lot on the choice of the operational strategy for the third terminal of passengers (TPS-3). The behavior is identical considering or not the existence of the third runway of landings and takeoffs. However, in both cases, they accompanied the tax of percentile growth of the delays.

As expected, the results generated starting from the simulation of the models 3 and 4 those that presented the minor values were when applied to the increase of 30% in the demand of aircrafts. Almost 75% of delays increase in the models 3 and 4, against 495% in the model 1 (current situation of infrastructure).

Completing the analyses of the study is necessary to confront the delays against the travel times accomplished by the aircrafts in their courses in the ground.

The third runway of landings and takeoffs possesses a small problem as for its operation already described previously. The aircrafts to reach the "new" runway threshold 09 will face a long taxi distance increasing therefore the travel time on the ground.

The aircraft would be less subject to the delays (happened in the gates, in the taxi-lanes and aprons), once the itineraries would not conflict with the existent procedures in the current taxi-lanes. However, the traveled time to the runway threshold 09 "new", in the case of takeoffs, would be high. The time spent for the arrival procedures would not be so accentuated, once the largest difficulty would be to reach the runway threshold 09 "new" for takeoff.

The results were practically the same, where the differential once again was the inclusion of the third runway of landings and takeoffs. The demand usually varied and the travel time also in the same way, in accordance with the same growth taxes.

On Figure 4, it is verified that the tax of growth of the travel time proceeded exactly to the tax of growth of the demand, generating a constant graph for their average values. Once constant, the difference can be measured by the average time the aircraft spent in the models where there is the inclusion of a new runway of landings and takeoffs and in the models in that the operations follow all for the same runway.

This time observed in Figure 4 is of 2 minutes. In other words, in the models where the new runway is considered, the operations were added by 2 minutes in relation to those that didn't considered the third runway.

According to Table 2, where the models differ for the existence of the new runway of landings and takeoffs, and of the new terminal of passengers, it can be verified that starting from an

increase of 14% in the demand of the operations in the Airport, the difference among their average delays passes 2 minutes. This value had been mentioned as the reference pattern on the average time of trip spent by the aircrafts that use the new runway of landings and takeoffs.

On Figure 5, it is noticed that when increasing 30% in the demand of the movement of aircrafts, the difference among the average values of delay for operation passes 5 minutes.

However, for demand values up to an increase of 14%, the delay among the models 2 and 5, and 2 and 6, turns smaller difference than 2 minutes, resulting non effective the construction of the third runway of landings and takeoffs, once the average travel time stayed constant in 2 minutes for any demand increase.

The installed capacity was not completely used for any of the mentioned cases. However there is a great tendency, starting from 30% in the increase of the demand of the movement of the aircrafts, that AISP/GRU, reach its operation limit quickly, above all in the model 1 that represents the operation situation lived in the days today, with many points of operational conflict.

However, one of the great problems visualized now at the airport regards the concentration of flights in certain schedules, causing excessive delays in certain hours of the day. The existence of idleness during other hours of the day made possible the operations in the simulations, although with many delays.

8. CONCLUSIONS
The viability of use of the methodology as an aid to the decision-making in airport planning is observed.

The study suggests that the construction of a third runway of landings and takeoffs, along with taxi-lanes, would bring more benefits in the long run (30% demand increase) of the operation of the airside as opposed to the solely construction of a new terminal of passengers (TPS-3).

However, the best option would be the construction of the 2 facilities, the new terminal of passengers and the new runway of landings and takeoffs. For an increment of 30% in the demand, the impact on delays would be very small, once the average delays would reach values close to the ones observed in 2000.

The new terminal of passengers alone would be operationally more effective than the third runway of landings and takeoffs up to 14% increase in the demand of the Airport.

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ANNEXES
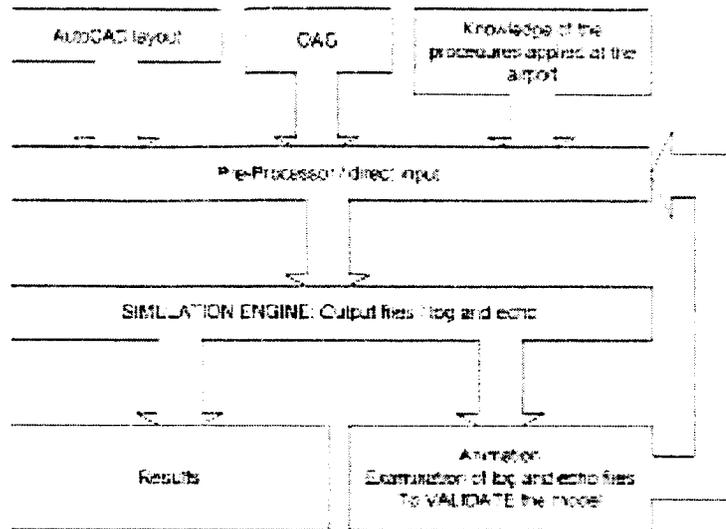
Figure 1. The Simulation Framework from SIMMOD Tool
Source: Delcaire &Feron, 1997

Operations (Real X Simulated)
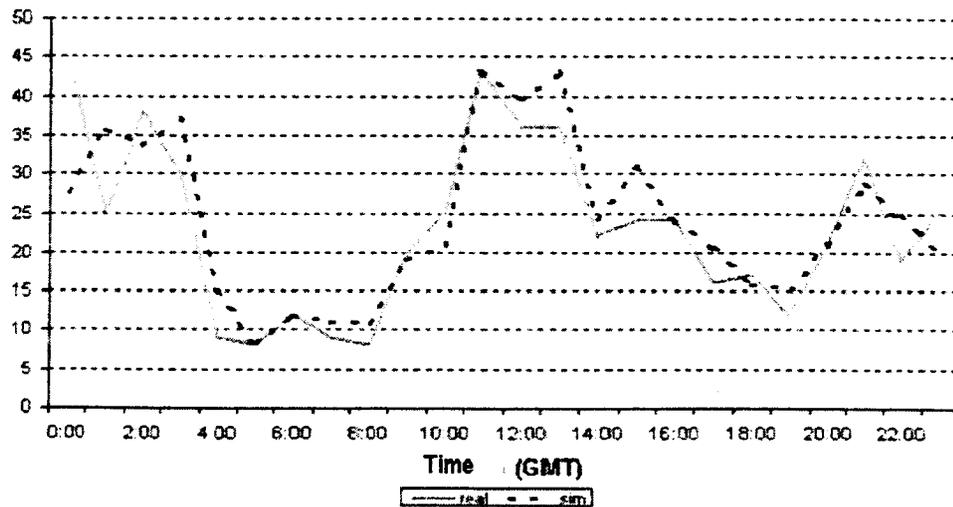
Figure 2. The Simulation Validation and Verification

Delays against Current Situation Model Scenario Base
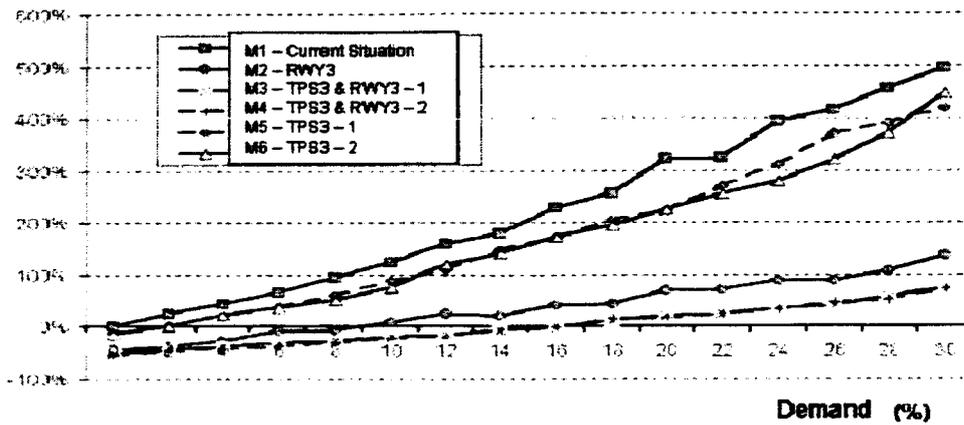
Figure 3. Simulation Results from 6 Models

TRAVEL TIMES – ARR + DEP (AVERAGE)
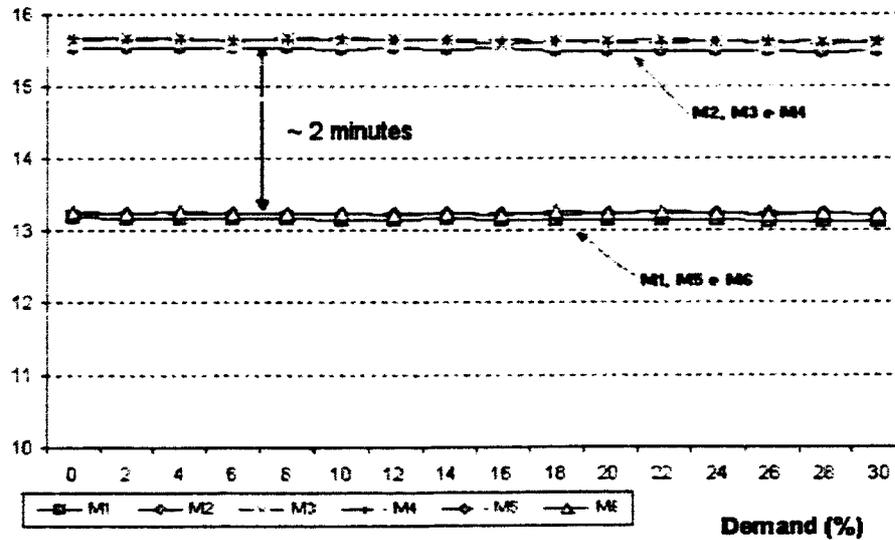
Figure 4. The Simulation Results – Travel Times (average) – 6 Models

DELAY – Min/OPER (ARR + DEP)
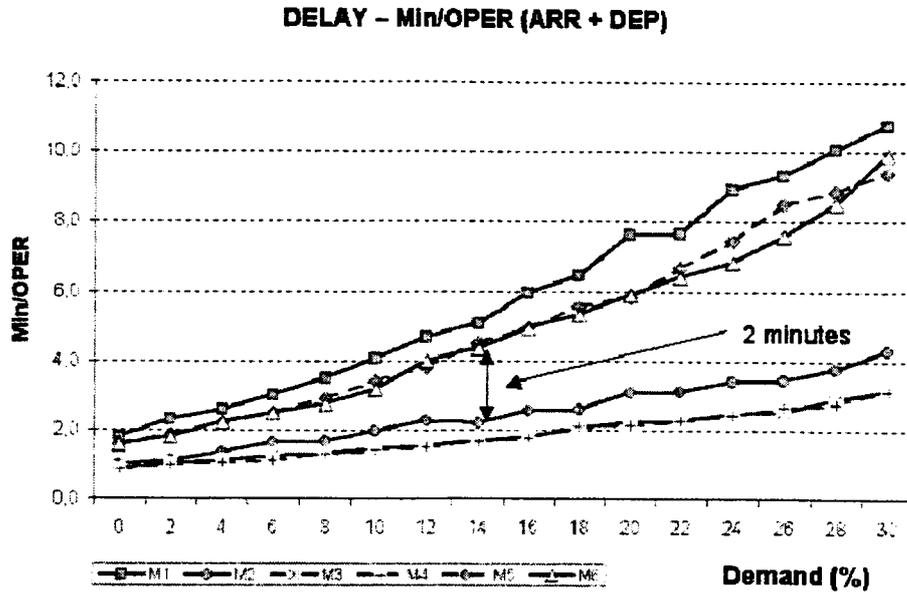
Figure 5. The Simulation Results – Delays (average) – 6 Models

Table 1. Aircraft's Operational Mix to AISP/GRU

Runways Using Percentile			
Aircraft	*Third Runway*	*09L/27R*	*09R/27L*
B737	100% arr	35,13% dep	64,87% dep
F100	100% arr 37,4% dep	62,6% dep	-
E120	100% arr and dep	-	-
F50	100% arr and dep	-	-
B767	26,56% arr	100% dep	73,44% arr
MD11	-	100% dep	100% arr
B747	-	100% dep	100% arr
A300	-	100% dep	100% arr

Table 2. Operational Mix for Third Passengers Terminal at AISP/GRU

	Star Alliance and others	43.91%	**TPS-3**
Scenario 01	**TAM e Group**	28.01%	**TPS-2**
	Vasp e Group	28.09%	**TPS-1**
	Long Haul Flights and Brazilian airlines	43.76%	**TPS-3**
Scenario 02	**Vasp e Group**	28.15%	**TPS-2**
	Domestic and Int. South America	28.09%	**TPS-1**

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JAL/JAS INTEGRATION -TOWARD A NEW ERA OF COMPETITION

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ABSTRACT

On October 2, 2002, JAL and JAS established a new holding company after obtaining the necessary approval from the government bodies. Full integration is planned to take place in April 2004.

This paper will primarily explain how JAL/JAS integration will enable JAL to compete effectively with ANA, the giant in the domestic market, and how it will reinforce JAL's competitiveness through further cost reduction and revenue enhancement.

In addition, the paper will explain how the keener domestic competition brought about by this integration could resolve the following two issues for the first time in the Japanese aviation history. Those two issues are: (1) providing better service to domestic customers, and (2) making Japanese airlines more competitive against foreign airlines in the international market.

As a result, the paper will argue that such an integration, a logical outcome of the post-war civil aviation history of Japan, will significantly benefit customers, Japanese aviation industry and Japanese society as a whole.

Keywords: Integration, Slot Constraints, Deregulation, Competitive Market

1. JAL'S LONGSTANDING ISSUE

<u>**(1) The need for a larger domestic market share.**</u> One of the longstanding issues for JAL has been on how to compete effectively with ANA in the domestic market. In order to do so, JAL needed to obtain a larger domestic market share that would enable more revenue from stable domestic market to alleviate or supplement the vulnerability of international operations.

Between 1970 and 1972, the Cabinet approved a framework for the aviation industry in Japan, based on the three major carriers, ANA, JAS (then TDA) and JAL. The main intention of this

framework was to restrict competition among the three airlines in order to foster and strengthen the internationally weak Japanese carriers at the time.

Under the 1970/72 policy, JAL was permitted to hold a monopoly of scheduled international routes, and to fly domestic trunk routes for the purpose of supporting financially its international operation. ANA's mission was to fly all domestic trunk and local routes, with permission to operate short-haul international charters. JAS was permitted to operate in the domestic market, serving local routes, with the promise of future approval for serving domestic trunk routes.

The international aviation market is very vulnerable to volatile economic, political and other unexpected factors such as exchange rates, terrorism, war and epidemics. JAL, being heavily reliant on revenues from international operation, has been impacted from such vulnerabilities, especially in recent years since the tragic event on September 11th, 2001. Therefore, in order to survive the cut-throat competition in the international aviation market, it is essential to establish a substantial business base in the domestic market.

In the United States, Pan American Airways and Trans World Airlines, whose main operational base used to be international, faded out after the introduction of the deregulation policy in 1978. On the other hand, the present mega carriers, American, United and Delta, started as domestic carriers. Under this deregulation policy, these mega carriers entered the international market. They have strengthened their international competitiveness through the fierce competition in the US domestic market, which is virtually free of airport slot restrictions. In each case their domestic revenue accounts for 70-80% of total passenger revenue **(see Fig.1)**.
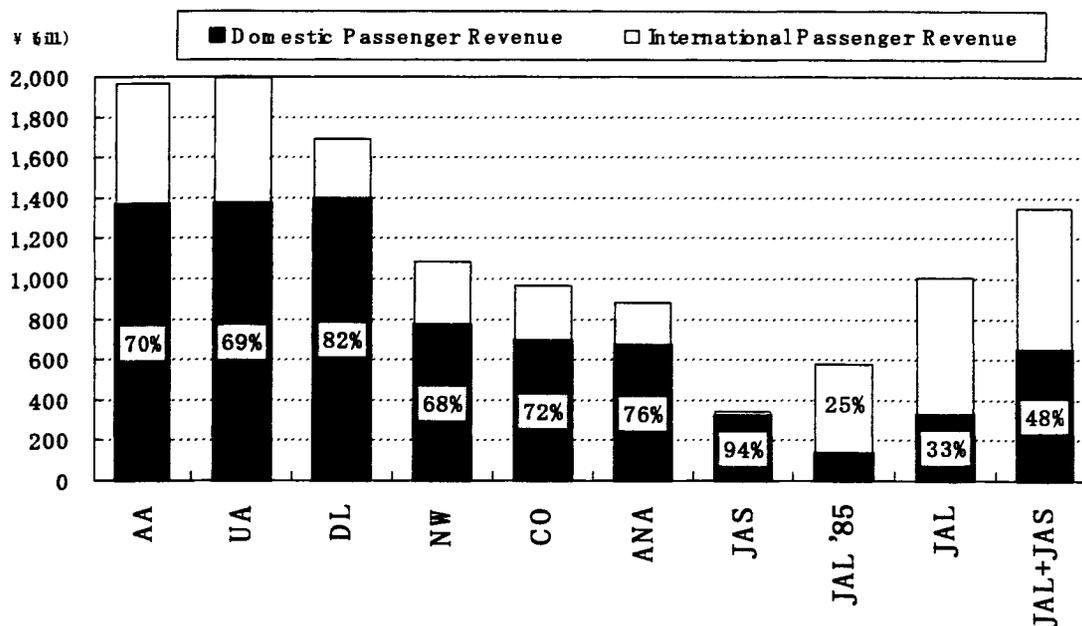
AA: American Airlines, UA: United Airlines, DL: Delta Airlines, NW: Northwest Airlines CO: Continental Airlines

Source : Airline Monitor (US Carrier) 、 Annual Report (Japanese Carrier)

Figure 1.

In Japan, 60 percent of all domestic passengers (95 million in FY01) use Haneda airport and 20 percent use Itami and Kansai airports respectively **(see Fig.2)**. However, Haneda and Itami

airports were at full capacity. Therefore, airlines have not had the freedom to increase their competitiveness by expanding market share at these extremely congested airports. This is even after the gradual deregulation policy that was introduced to the domestic market in 1986, and the complete deregulation, at least in principle, that followed in 2000. These deregulation policies are only true in principle since the break-down of domestic market shares under these policies has been almost exactly the same as it was 30 years ago: ANA 50%, JAS 25% and JAL 25% (see Fig.3). The ratio of domestic passenger revenue to that of international in the regulated era has also remained virtually unchanged even after the deregulation policy was introduced, which is completely different from that in the United States: 3:7 in case of JAL, 8:2 for ANA and 9:1 for JAS (see Fig.1).

International Passenger Number
46.9 mil (FY 2001)

Domestic Passenger Number
94.6mil (FY 2001)

International cargo and domestic cargo also concentrated at
· Narita and Haneda airport respectively

Osaka=Itami+Kansai

Source　Ministry of Land, Infrastructure and Transport
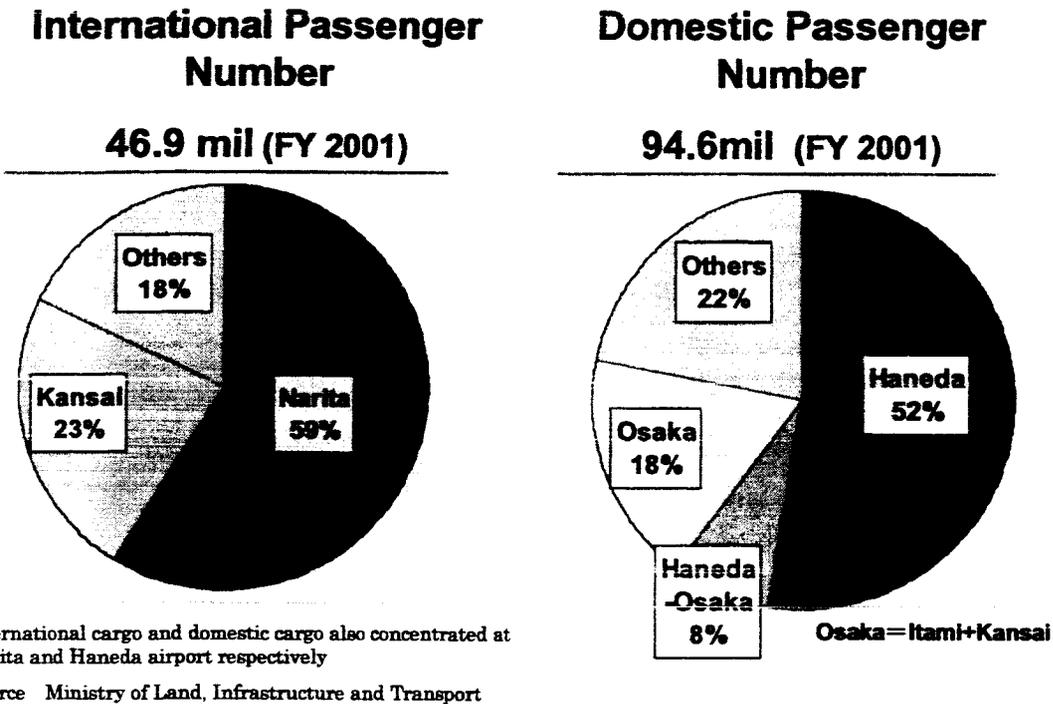
Figure 2.

(2) Three Measures to Address JAL's Longstanding Issue

The following three measures are expected to resolve the JAL's longstanding issue of drastically increasing its domestic market share up to the level of ANA's:

1) To obtain JAS' consent to integrate with JAL, which would make its domestic market share almost to the same level with ANA's instantaneously;

2) To have the airport capacity at Haneda airport expanded by the government through the construction of a new fourth runway so that JAL can increase its market share freely;

3) To rectify completely the substantial slot share disparity among three major airlines at Haneda and Itami by the government through the slot allotment.

JAL had worked on JAS to form some types of partnership to compete with ANA effectively since the latter half of 1980s', and JAS finally agreed to the integration this time and hence, the

first measure was realised. This integration has created a well-balanced domestic and international structure suitable for competing effectively in the international market. Domestic passenger revenue for the newly integrated company becomes close to 50% of total passenger revenue (see Fig.1).

FY2001
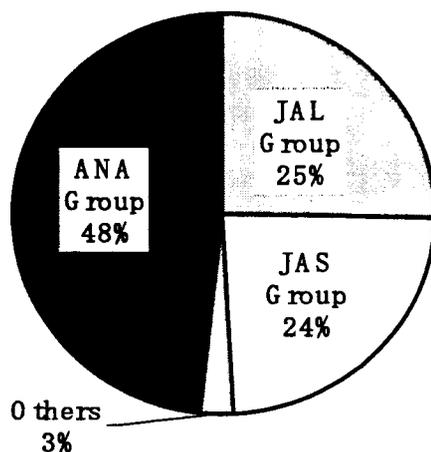
Others= Skymark Airlines, AirDo, etc.

Figure 3.

The second measure is likely to take much more time for it to be realized than the first measure.

Regarding the third measure, as reported by the Committee for Setting Standards on Distributing New Slots at Haneda in 1997, the Japan Civil Aviation Bureau (JCAB) announced its intention to rectify the disparity of the slot share at Haneda at the time of the Haneda's capacity expansion (see foot note).

Note: the capacity at Haneda was expanded to some extent at the time of the completion of the offshore relocation of runway C in 1997 and runway B in 2000.

However, as the government has set aside slots for new entrants since 1997 and also has adopted the evaluation-based slot allocation method since 2000, by which the government would distribute slots on the basis of each airline's performance, the slot disparity could not be expected to be rectified drastically, even in the longer term.

2. THE REINFORCEMENT OF JAL'S COMPETITIVENESS

Following the Gulf War in 1991 and the worldwide economic recession thereafter, international passenger demand has fallen against the previous year for the first time in the world aviation history and as a result, the competition had become fiercer. Meanwhile, the growth rate of the domestic demand has also become sluggish, causing over-capacity in the market. The average yield of the international passenger fell by about 40% and that of the domestic passenger by about 30% in the last 12 years.

Under these circumstances, JAL has drastically cut costs by more than 30% per ASK (available seat-kilometres) in 12 years. In terms of the unit labour cost, the reduction is about 50% without lay-offs (see Fig.4). In Japan, layoff should be avoided as much as possible and must be considered only as the last resort. Such a practice is a prevalent in Japanese society.
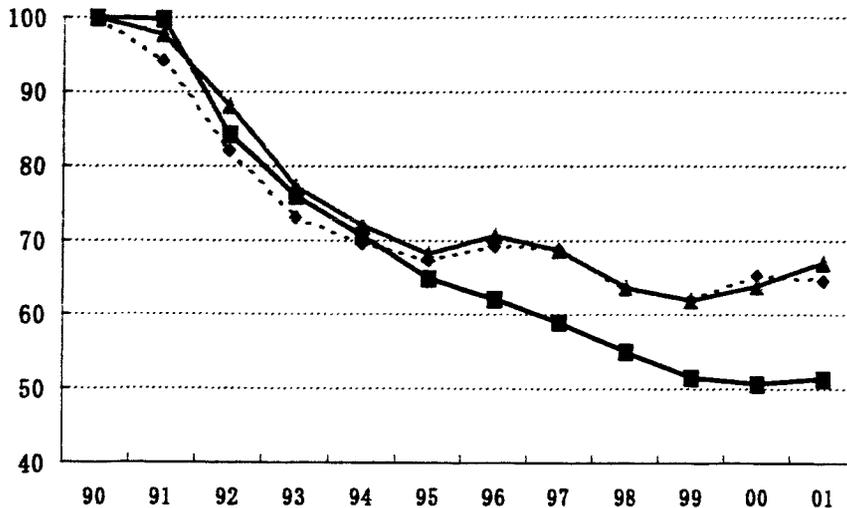
Figure 4.

Although JAL finally recovered in 1998 and succeeded in recording profit, the terrorist attacks in the U.S.A in September 2001 forced JAL back to a serious financial loss.

In this unprecedented severe environment, where the need for a fundamental change in the cost and revenue structure was called for more than ever before, JAL has been forced to search for new ways to further cut costs and increase revenue. One of the main solutions to this challenge was the JAL/JAS integration.

(1) Further Cost Reduction

The shared use of equipment such as aircraft, ground service equipment, facilities and personnel contributes to the cost efficiency and reduction. JAL/JAS (hereafter JAL Group) originally planned to save ¥61 billion (=US$510 million) annually by the end of March 2006 .

Estimated amounts of cost reduction of each segment are as follows: ¥19 billion (=US$160 million) reduction from reduced rental fees; ¥28 billion (=US$230 million) saving from labour efficiency improvement; ¥ 11 billion (=US$90 million) saving from fleet efficiency improvement and ¥3 billion (=US$25 million) saving from others (see Fig.5). The number of aircraft types is 16 at present and it is planned to decrease to 11 by FY06.

Because revenue is falling drastically due to the impact from the war in Iraq and SARS, which were not considered at the time of planning the integration, JAL Group is making utmost efforts to accelerate the pace of the cost reduction plan, aiming to complete well in advance of the original target date.

Reduction of rent etc. ▲\ 19 bill. (=$160 mill.)
• Consolidation of branches
• Effective use of Airport Facilities

Job Reductions ▲\ 28 bill. (=$230 mill.)
•Reduction of 3000 jobs

▲\ 61 bill. (=$510 mill.)
Effect in FY 2005

Fleet Reduction ▲\ 11 bill. (=$90 mill.)
• Investment Reductions
• Reduction of Aircraft &
  Maintenance Cost

Other Reductions ▲\ 3 bill. (=$25 mill.)

Figure 5.

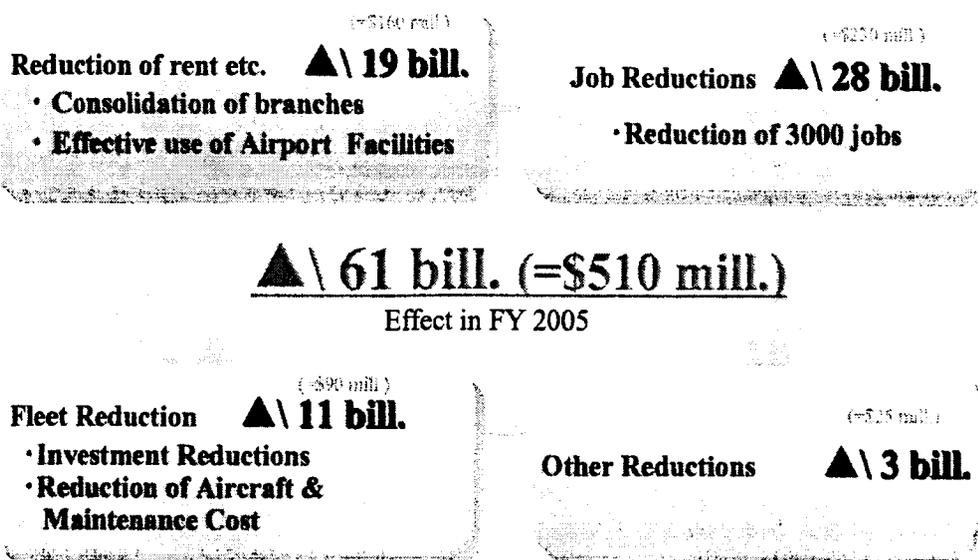## (2) Further Revenue Enhancement

As explained earlier, JAL's domestic network is composed primarily of trunk routes and that of JAS local routes. This means both are in a mutually complimentary relationship. With the integration, the JAL Group has roughly an equal share of slots to ANA group at Haneda and Itami, resulting in a broader, nationwide network. The former "one strong + two weak airlines" structure is changed into the new one where two airline groups, JAL and ANA become real, equal, competitors. JAL Group can now offer a more competitive and, more customer oriented flight schedule, network, fares and services as a market leader. After 8 months have passed since the integration came into effect, it is quite clear that the JAL Group's competitive position against ANA group has become much stronger. The examples of strengthening of the network and schedule competitiveness are as follows:

1) Starting flights on high-demand routes monopolised by ANA (Toyama, Yamaguchi-Ube etc.);
2) Scheduling more flights on high-demand profitable routes where ANA had a larger number of flights (Matsuyama, Hiroshima);
3) Eliminating over-concentration of flights at the peculiar peak hours on trunk and other routes to set user-friendlier timetables (system-wide).

We expect an annual ¥21.5 billion (=$180 million) increase in revenue in FY06 because of increased competitiveness but, at the same time we expect an annual ¥11 billion (=$90 million) decrease in revenue because of active sales promotion. Therefore, the net expected increase in revenue is ¥10.5 billion (=$90 million).

At the bottom line, we expect the net integration gain of annual ¥56 billion (=$470 million) in FY05 and thereafter (see Fig.6).

(Yen in billions)

	FY2002	FY2003	FY2005	
Revenue Enhancement	0	12.0	21.5	
Fall in Revenue	▲ 5.5	▲ 11.0	▲ 11.0	
Cost Reduction Effects etc	1.0	18.5	61.0	($ in millions) $1=120
Total Integration Effects	▲ 4.5	19.5	71.5	(=$600m)
Additional Cost Increase	▲ 6.0	▲ 6.0	▲ 15.5	
Net Integration Effects (Costs Incurred)	▲ 10.5	13.5	56.0	(=$470m)

Figure 6.

(3) Current Progress and Short-Term Goal

With this integration, JAL Group has a well-balanced revenue structure with revenue share of international passenger 41%, domestic passenger 38%, international cargo 10%, domestic cargo 2% and others 9%. The international passenger segment also has a well-balanced revenue structure with revenue share of Pacific routes 29%, European routes 20%, long range Asian routes 21%, short range Asian routes 20%, and others 10% (see Fig.7).

It surely seems that JAL's decision to integrate with JAS was very timely considering the unexpected outbreak of war in Iraq and SARS turmoil.
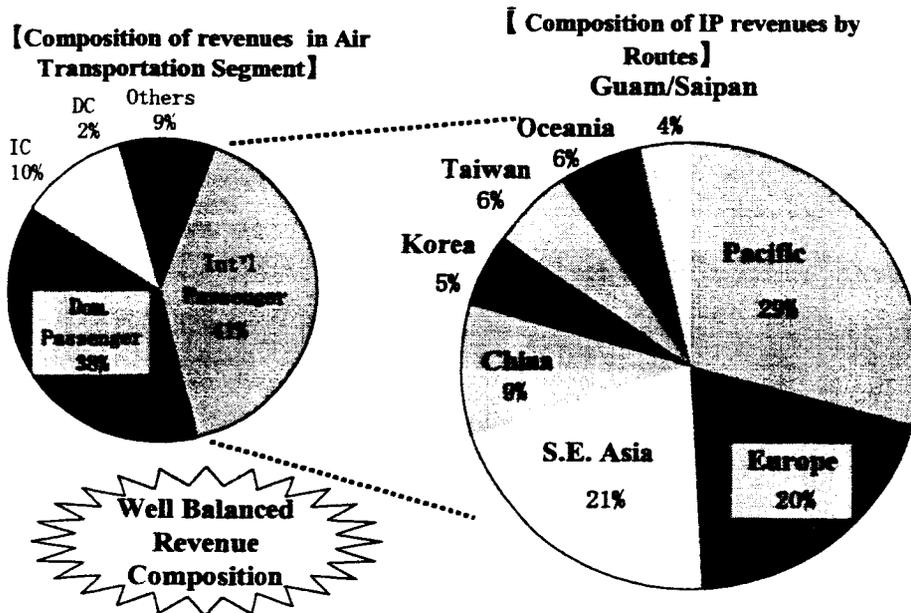
Figure 7.

The progress of integration, including computer reservation systems, is under way and controlled very well so far without any serious problems. After full integration in April 2004, JAL Group will consist of Japan Airline Domestic and Japan Airlines International (which includes cargo business at the beginning). Cargo business would become independent in the future, circumstances permitting (see Fig.8).

Within FY2003 Speeding up the reorganization of management structure in preparation for Phase 2

April, 2004   Transition to the following business structure to maximize Integration effects
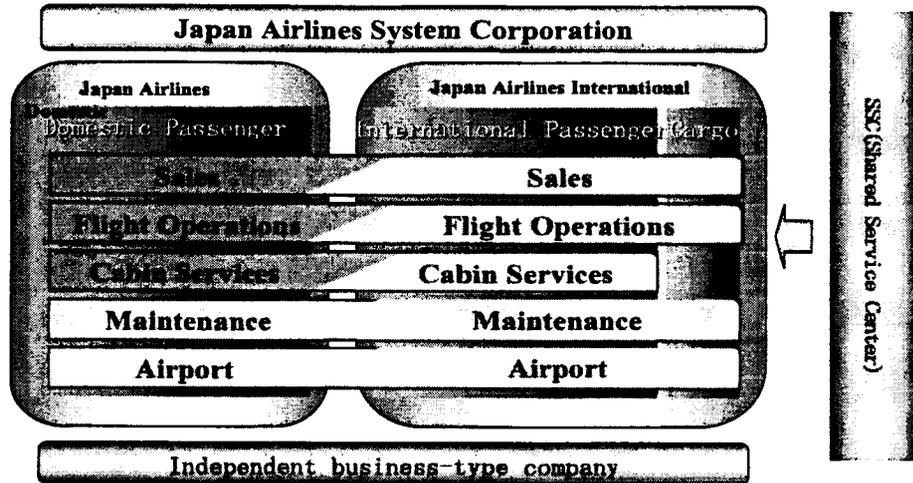
Figure 8.

With SARS and the aftermath of war in Iraq, we are forced to expect financial losses in FY03. However, as the effects of both events are likely to fade away by the end of this fiscal year, combined with the revenue structure change brought about by JAL/JAS integration that can partially offset the ill effect on the international business, we still expect profit in FY04 and FY05 (see Fig.9).

(Yen in billions)

New Japan Airlines Group	FY2000 (Results)	FY2001 (Results)	FY2002 (Results)	FY2003 (Estimate)	FY2005 (Target)	$=\120
Revenue	2,122.2	2,029.5	2,083.4	2,032.0	2,245.5	(=$18.7 bill.)
Operating Profit	96.3	▲1.0	10.5	▲22.0	122.4	(=$1018 mill.)
Operating Profit Margin	4.5%	0.0%	0.5%	▲ 1.1%	5.5%	
Net Income	43.2	▲35.8	11.6	▲43.0	34.9	(=$290 mill.)
ROE	15%	▲14%	5%		12.4%	
Payback Period (Interest-bearing Debt / Operating CF)	9 years	15 years	12 years	15 years	7.7 years	

Figure 9.

Notwithstanding above, as almost all airlines in the world including U.S. mega-carriers are cutting cost drastically under the severe financial situation, and are desperate to regain the international competitiveness, JAL Group is required to make further cost reduction and revenue enhancement than originally planned in the integration project.

It is noteworthy that although China is badly affected by SARS for now, in the long run, it will grow to become a giant aviation market in the world. JAL Group must be prepared to reap the benefit from this lucrative growing market with the determination to lower cost to the level of Asian airlines.

3. TWO LONGSTANDING ISSUES IN AVIATION INDUSTRY IN JAPAN

The aviation industry in Japan has had the following two longstanding issues, indirectly explained so far. Both issues are expected to be resolved simultaneously by this JAL/JAS integration;

1) The need for improving customer services that had been seriously hampered by the imperfectly competitive domestic air travel market in which one airline, ANA, dominated half of the market share, while the other two, JAL and JAS, with less than one-quarter of the market share each, had to compete with this "Giant Share holder" (see Fig.3).

2) The need for reinforcing the competitiveness of Japanese airlines as a whole against foreign airlines in order to expand the international network of the Japanese airlines and to increase Japanese airlines' share of the international passenger market in Japan, which is now only around 40% (see Fig.10).
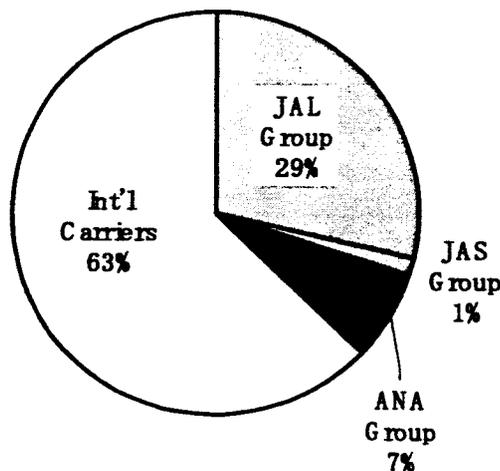
FY2001

Figure 10.

As explained above, the integration of JAL and JAS has changed the existing structure of "one strong + two weak airlines" to a new structure where two airlines are real competitors. It is thus quite natural that the competition is stimulated more strongly than before.

The more competition Japanese airlines are exposed to in the domestic market, the more competitive they will become, especially in the area of cost reductions, which will in turn make them more competitive against foreign airlines. As has been said, the American mega-carriers boosted their competitiveness by competing fiercely in the domestic market first.

Although ANA's international passenger revenue is smaller than that of JAL group, this difference is expected to shrink rapidly if ANA makes full use of the restriction free slot situation at Narita and Kansai in the same way ANA has expanded international routes so far.

In terms of international passenger market share of Japanese airlines in Japan, it has stayed at around 40% even after ANA entered the international passenger market in March 1986, followed by JAS in July 1988. Unlike the domestic market, the slot restriction at Narita was loosened by the opening of its second provisional runway in April 2002, and strong growth is expected in the medium to long term.

Therefore, the task for Japanese airlines is to become more competitive internationally and to increase its market share through expanding the international networks. This will open ways for Japan's increased participation in the international arena in the area of economics and politics, and hence will contribute significantly to improving the lives of the people.

4. CONCLUSION: 50 YEARS OF CIVIL AVIATION HISTORY IN JAPAN A NEW FRAMEWORK IS NEEDED

Civil aviation in Japan, following Japan's defeat in 1945, resumed in October 1951 when the first Japan Air Lines took to the sky. Between 1952 and 1953, eight other domestic airlines were born.

Of these eight, four were eventually folded into ANA by 1967. The remaining four eventually merged to become Toa Domestic Airlines (TDA), renamed Japan Air Systems in 1988. Therefore, mergers like JAL/JAS integration are nothing new in Japanese aviation industry.

Protective Aviation Policy Until 1985

During the 1960's, the demand for air travel grew strongly as the Japanese economy surged and annual GNP growth soared. Although Japanese airlines struggled to increase capacity to meet the demand, they were hindered by a shortage of pilots and delays in developing airports. Circumstances demanded a clear aviation policy.

Between 1970 and 1972 the Cabinet approved a new business field demarcation of the three major carriers established, then ANA, JAS (then TDA) and JAL.

The main intention of the 1970/72 policy was to protect and nurture the airlines by avoiding the excessive competition among themselves.

JAL, the senior company, was permitted to hold a monopoly of scheduled international routes and to fly domestic trunk routes for the purpose of supporting financially its international operation. ANA's mission was to fly all domestic trunk and local routes, with permission to operate short-haul international charters. JAS was permitted the domestic market, serving local routes, with the promise of future approval for serving domestic trunk routes

Gradual Deregulation Policy After 1986

However, in the early 1980's, as both the domestic economy and the airline business were growing strongly and being influenced to some extent by a new US-Japan aviation agreement in 1985 that permitted multi-designation of Japanese carriers to transpacific service, the government adopted a new, pro-competition policy in 1986.

Under this policy ANA and JAS gained rights to operate the international scheduled service. In return JAL got more access to the domestic market through more local routes.

At the time, there was already capacity shortage at the main domestic airports, Haneda and Itami. Regarding the capacity of the main international airport, Narita, it was opened in 1978. Its capacity was saturated in 1991 and loosened again in April 2002 by the opening of its second provisional runway.

Total Deregulation Policy in 2000, but incomplete

The next major policy change came in February 2000, when "total deregulation" was launched in the domestic market. The domestic restrictions on air fares were completely lifted and airlines were permitted to fly wherever they liked.

However the problem was that the persisting lack of capacity at the key airports, Itami and Haneda, prevented airlines from starting new routes on monopolised routes and increasing flight frequencies on other double or triple trucking routes where in most cases ANA enjoyed largest number of frequencies. Thus the breakdown of the domestic market shares under the new "totally deregulated" policy was almost exactly the same as it had been 30 years ago: ANA 50%, JAS 25% and JAL 25%.

Base on the strongest competitiveness of the network promised by the given "Giant Share" in the domestic market, ANA had held firmly the marketing initiative. This is because why it has been said that the competition in the domestic market is less fierce than that in the international. It could be said that the free and fair competition which is clearly stipulated by the Japanese antitrust law was appeared flawed to some extent under the reality of imperfect market conditions, aggravated by airport capacity shortages.

The JAL/JAS Integration, The Logical Outcome Of The Japanese Aviation History

The integration was the only one last choice left for the minor airlines in the domestic market unless the government took the necessary actions to dissolve the basic contradiction of the deregulation policy with the chronically crucial slot shortage at the main domestic airports. By this integration, the competition in the domestic market is substantially promoted and it becomes possible to solve the longstanding issues of the Japanese aviation, that are;

a) Improve customer services
b) Reinforce the competitiveness of Japanese airlines as a whole against foreign airlines

The Study of Airline Merger and Acquisition in the Greater China Area

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Abstract

The Asian financial crisis in the late 20th century has some long lasting effect on the air transportation industry in Asia, especially in the Great China Area. Starting from 1998, airlines in both China and Taiwan suffered some serious financial losses due to the diminishing travel demand caused by the economic recession. Airlines were forced to cut price to attract passengers and hence crashed the market discipline. A number of airline mergers and acquisitions were then driven by the markets and the governments. After China and Taiwan have both entered the World Trade Organization, some mega-merging cases were finalized in late 2002 for better fitting the world's aviation competitions.

This paper reviews the nine merging and acquiring cases in the Great China Area in the past 5 years. Almost all the airlines in the area were involved. The new groups of airlines and the survival airlines are introduced. Market response to the airline mergers will also be examined. A general look over the performance of the new airlines will be discussed. And the future of the market will also be analyzed. Finally, the practices and the impacts of current inter-state mergers in the Great China Area will be examined. The study has expected a highly concentrated domestic market in both China and Taiwan. Each of the market will be dominated by three major airline groups of their own. Cross-holding equity within these 6 leading aviation groups would also be possible after further deregulations.

1. Introduction: The History of the Airline Industry in the Greater China Area

The airline industry in China can be traced back to the late 19th century. However, there is not any single carrier that can survive for over a hundred years. The current aviation industrial structure was established during the 1930s to 1940s when both Cathay Pacific and China National Aviation Corporation (CNAC) were established. These two carriers are still some most important airline groups in the Greater China Area today. Cathay Pacific was set up in 1946 in Shanghai as a private business, while CNAC was setup in 1930 in Nanjing as a state enterprise. The role of CNAC is quite embarrassing after the ROC regime was turned to PRC in 1949. Some pilots threw their lot in the communists and flew their aircraft to Beijing. These pilots and aircraft were then become the basis of the following monopoly air carrier in China, the Civil Aviation Administration of China. CAAC is the administrative bureau of civil aviation. Following the Soviet bureaucratic structure, it was also providing the monopolistic air transportation service. The carrier of bureau has operated for over 30 years until the first deregulation act made in 1985. The deregulation policy, which should be considered as a revolution to decompose the aviation industry, was mainly for the purpose of separating business sector from administrative bureau. By then, some new state enterprises were created, and some regional or provincial carriers were also introduced. The entire aviation industry of China has been expended to 26 carriers within a few years. A brand new era for the aviation industry was come, not only because of the number of carriers was increased, but also the efficiency and service quality was improved.

On the other hand, by losing all the aircraft during the civil war, the ROC regime which retreated to Taiwan in 1949 was not able to run aviation business anymore. The state owned aircraft grounded in Hong Kong was then sold to General Claire Lee Chennault, the leader of Flying Tigers in China, in a very affordable price before the property rights of these aircraft could be transferred to PRC. General Chennault used these aircraft established Civil Air Transport (CAT) in Taiwan, while other members of Flying Tigers established Flying Tiger Line in US. CAT went bankrupt a few years' after the Vietnam War. The China Airline then took over their business in Taiwan. Established in 1959, China Airlines was the last one of the first three airlines set up in the 1950s. All the three carriers are still operating today, regardless of their heavy losses. After China Airlines was set up, an entry barrier of air transportation industry was successfully built to keep competitors away from the market for over 30 years. In the early 1990s, Eva Airways broke the barrier by modifying the aviation law through Legislators supporting

them, probably also supported by them. A deregulation policy was then made to welcome new players in the market. Within a few years, the number of airlines in Taiwan has expended from 3 to 9. Private sectors were investing huge amount of money because the aviation industry under protection was a real profit one.

Meanwhile, new carriers in both Hong Kong and Macau were also introduced during the mid of 1980s and 1990s. Dragon air, the second airline of Hong Kong, was established in 1985 focusing mainly on the air transportation market of China. 10 years after the Dragon air, Macau has also launched a new airport with a new airline, the Air Macau. Air Macau is also an airline of Greater China market. Although these two airlines have big similarities in product positioning, yet the huge demand across the Taiwan Strait has still made these two carriers profitable during the past years.

2. Post-deregulation Effect: Merger and Acquisition

It seemed like most nations having deregulation policy towards aviation industry have experienced some similar transformation of the market structure after deregulation. In the first phase of deregulation, numerous competitors are appearing soon after the entry barrier is broken. Nonetheless, airlines have big sunk cost. Deregulation policy has made airliners easy to get in, but hard to get out. This is just one worst market structure can be found in some basic marketing theories. Deregulation policy was based on the belief of market mechanism, but the mechanism has also defaulted the economic effect of deregulation. As most marketers' prediction, airline business soon turned non-profitable after deregulation. Any change from the operating environment will cause serious damage of the entire industry. In the past 20 years, lots of mega-carriers went bankrupt in US and Europe, and a number of airline mergers and acquisitions occurred each and every year. Any single political or economic factor, including terror attacks, war, even economic recession or business competition, could have huge impacts on airlines' operations. Not surprisingly, airlines in the Greater China Area have to face the same problem.

The Asian financial crisis in the end of 20th century was one last, probably the most important factor to encourage airline mergers in the great China area. Although none of the carriers went bankruptcy, most carriers were losing big money. The idea of airline mergers was than proposed by some economists in China. Long before Asian financial Crisis, scholars in Taiwan have also encouraged airline merger to reduce the negative effects of deregulation. Together with some acquisitions, we have concluded 7 M&A

cases after 1990s. These cases are:

1. Air China Group:

   Air China Group was a combination of 3 different airlines: Air China, China National Aviation Corporation, and China Southeast airline. Air China was the flag carrier, it is still the one and only flag carrier after mergers. One interesting fact in this group is the role of CNAC, the China National Aviation Corporation. It was and still is the stock holding company of both Dragon Air, Air China, and one small regional carrier Zhejiang airline. That is to say, Air China Group nowadays controls 5 airlines altogether. The total asset of Air China Group is 57.3 billion REM, approximately 7 billion US dollars. They have 119 aircraft and 307 links in total. The number of employees is now 22960.

2. China Eastern Airline Group:

   China Eastern Airline Group is based in Shanghai, one attractive and energetic city with fastest growing economy in China. In addition to the original China Eastern Airline, the group also integrated Yunnan Airline and China Northwest Airline. The new China Eastern Airline Group is now an airline with 47.3 RMB billion assets, 142 aircraft, 386 links, and 25000 employees.

3. China Southern Airline Group:

   China Southern Airline was the first Chinese airline that went public in Hong Kong and New York. Based in Guangzhou, China Southern Airline has enjoyed the successful economic reform during the 1980s and 1990s. Although the focus of China economy has moved up to Shanghai and nearby areas, Southern China has still been beneficiated, and so has the China Southern Airline. It was the most efficient airline in the past 20 decades. The group integrated China Southern Airline, China Northern Airline, and Xinjiang Airline. The New China Southern airlines is having 50.1 billion RMB assets, 180 aircraft, 666 operating links, and 342686 employees.

4. China Airlines Group:

   Across the Taiwan Strait, there are also some merging cases of airlines. The China airlines, which holds 100% of mandarin airlines, is one biggest aviation group in Taiwan. In the aviation market, there is no merging record of this carrier, because China Airlines has only acquiring some domestic carriers instead of merging. Currently

China Airlines is still holding some minor shares of Far Eastern Air Transport, one most important carrier in the domestic market. China Airlines have also had over 90% shares of Formosa Airline, one disappeared carrier in the market.

5. Mandarin Airline and Formosa Airline

Both these two airlines are belonging to China Airlines. China Airlines is holding 100% of Mandarin and majority shares of Formosa. The functions of Mandarin and Formosa were divided into international brand and domestic one. The reason to set up Mandarin was because of the too-sensitive role of flag carrier in some specific regions; and the reason to hold Formosa was because of the allocation of time slots in the very congested Taipei airport during the 1990s. However, the Formosa Airline was bad at the air safety records. Fatal accidents happened year after year. Finally China Airlines decided to terminate the operation of Formosa, but still want to hold the traffic rights in some domestic links. The group asked Mandarin to merge Formosa in 2000 as a result.

6. Eva Air Group:

Eva Air is the airline of Evergreen Group, one of the major marine liner groups in the world. In the late 1980s, Evergreen decided to expand their business from marine liner to one fully integrated logistic empire, so they decided to break the entry barrier of air transportation law in Taiwan, also initiated some ground transportation services. The Eva Air was successfully established in the early 1990s. They also acquire one small carrier in Taiwan to serve the domestic market. This airline was Makung Airline, which turned into Uni Airways afterwards.

7. Uni Airways Mergers

Uni Airways was the former Makung airline acquired by Eva Air. Evergreen decided to transfer the property of the carrier to one of its sub-company, the Uni Liner. So the name of Makung was then changed in the mid 1990s to Uni Airways. To enhance the competition power in the domestic market, Eva decided to acquire 2 other small carriers in Taiwan: The Taiwan Airways and Great China Airways. Soon after Asian financial crisis, Evergreen Group has decided to cut cost and condensed the business scale. All 3 domestic carriers were merged. The existing airlines has chosen to be the Uni Airways.

8. Hainan Airlines

The most interesting case of acquiring the airlines in the Great China Area should be

the Hainan Airlines. Hainan Airline is the first airlines trading both A shares and B shares in the China Stock Market. The critical ratio of equity was acquired by private sectors during the Asian financial crisis. Some other airlines were also acquired in 2002 while major state-owned airlines group were restructuring. Nowadays Hainan airlines group has been the biggest private owned carrier in China. Deer Jet Company Ltd., Chang'an Airlines Company Ltd., Shanxi Airlines, China Xinhua Airlines Company Ltd., and Yangtze River Express Company are all under control of Hainan Ailines. The entire group is now holding 80 aircraft in total.

3. Cross Border Acquisitions

In addition to the local merger and acquisition cases discussed above, cross border acquisitions are also easy to find in recent years. Although the political relationship within the Greater China Area is complex, cross border equity holding in this area is still popular. All the four states and regions have involved such sensitive business activities, but all maintain very low profile. Four major cross border acquisitions are:

(1). China on Hong Kong:
CNAC is now the biggest share holder of Dragon Air. Nonetheless, the history of taking these shares of Dragon Air from Cathay Pacific was an unpleasant experience. In 1995, Eva Air in Taiwan has again broken the market entry barrier and successfully penetrated the monopolistic market between Taiwan and Hong Kong. In order to balance the pressure from two large carriers from Taiwan, China has express their willingness to join the market, and asked Hong Kong adding one more carrier to serve the Hong Kong-Taiwan market. The only choice was Dragon Air who was controlled by Cathay Pacific at the time. China then forced Cathay Pacific to give up certain shares of Dragon Air to keep Cathay's capacity in the world's busiest air link. CNAC finally took over Dragon Air, and the economic power of China has started to play a role in Hong Kong's air transportation soon after this successful acquisition.

(2). China on Macau:
CNAC is also the biggest share holder of Air Macau since establishment in 1995. This is about the same time when CNAC took over Dragon Air. But since Macau is less sensitive in both political and economic affairs, also because CNAC has involved since very beginning, the process of holding Air Macau by CNAC is much

easier than holding Dragon Air in Hong Kong. Lacking direct services between Taiwan and China have given Hong Kong and Macau one great niche market to survive, both Air Macau and Dragon are doing quite well in the Greater China Market, thus make CNAC profitable in the past decade.

(3). Taiwan on Macau:

The relationship between Hong Kong and China or Macau and China has already been confirmed in the late 1990s. Both Hong Kong and Macau are now the Special Administrative Region (SAR) of China, but it's not yet clear whether Taiwan will accept this arrangement or not. Obviously, any merger or acquisition between Taiwan and the rest of China can be very sensitive. Nonetheless, Eva Air has done a great job in acquiring certain shares of Air Macau. Eva acquired 10% shares of Air Macau from the former colony Portugal government and business in Macau. As Portuguese may withdraw from Macau entirely, Eva Air could probably acquire more shares in the future, hence made them the second biggest power in Air Macau.

(4). Taiwan on China:

The most difficult acquisition should be acquiring firms across the Taiwan Strait. Even so we can still find one successful story of China Airlines and China Eastern Airline Group. China Airlines has successful acquired 25% of China Cargo Airlines, one of the two cargo airlines in this region in 2002. The share was transferred from China Eastern Airline Group, one of the only two share holder of China Cargo Airline. This acquisition has been suspended for over 12 months to get the approval from the administrations of both sides. This case is even more sensitive than Eva Air acquired Air Macau since the relationship between Taiwan and China are still unstable.

Figure 1 illustrates the relationship of the current airlines within the Greater China Area. Both local and cross border airline mergers and acquisitions are included. They are, however, only existing M&A cases listed in this chart. Potential M&A cases are not yet introduced. Future integration in 2 domestic carriers in Taiwan is likely to happen, while some individual local carriers in China are initiating strategic alliances to increase their competition power. These possible horizontal integrations are concluded in Table 1.

7

China Airlines

Mandarin Airlines

Fomorsa Airlines

China Eastern Airlines

China Northwest Airlines
Yunnan Airlines

China Cargo Airlines

China Southern Airlines

China Northern Airlines
XingJiang Airlines

Eva Airways

Cathay Pacific

Air Hong Kong

Uni Airways

Taiwan Airlines

Dahua Airlines

Air China

Air China
China Southwest Airlines

Dragon Air

Deer Jet

China Xinhua Airlines

China National
Aviation Corporation

Air Macau

Yantz River Express

Hainan Airlines

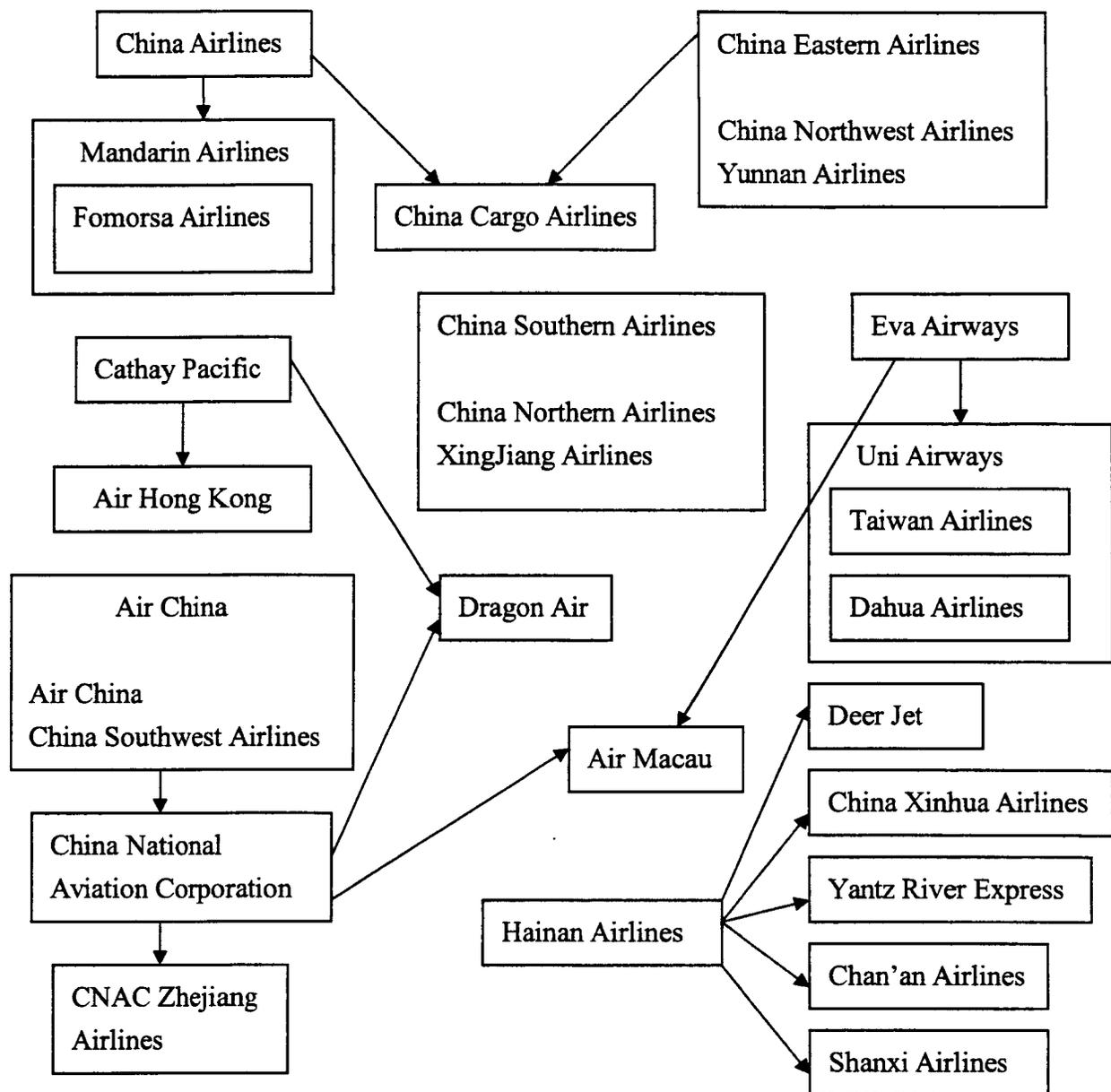Chan'an Airlines

CNAC Zhejiang
Airlines

Shanxi Airlines

FIGURE 1 Relationship of Airlines in the Greater China Area

Table 1 Possible Airline Integration in the Future

Involving Carriers	Description
Far Eastern Air Transport TransAsia Airways	Major share holders are seeking the possibility to integrate these two carriers in Taiwan
China Postal Airlines, Shanghai Airlines, Shandong Airlines, Wuhan Airlines Sichuan Airlines, Shenzhen Airlines	Carriers in China out of 3 major airline groups and Hainan Airline group sought strategic alliance

4. Problems of Airline Mergers

Since the merging and acquiring activities occurred at a very high frequency, some problems can easily been observed during these transitions periods. Operational, organizational, managerial, and financial problems are the most serious ones which includes:

1. Performance after mergers and acquisitions

    One most important issue of M&A is evaluating the performance of merging and acquiring company after M&A. A number of researches are focusing on this issue, but never on the airline industry. Some indexes of both production and finance are developed to measure the performance between pre-M&A and post-M&A. Stock price, passenger-mile, ton-mile, labor and capital productivity are all commonly used in evaluating airlines' performance. Nevertheless, the airline M&A in the Greater China Area is still too new to have these comparative analysis Within one year or two, these numerical tests are valuable topics in both academic researches and practical studies.

2. Managerial and culture conflicts

    Any kind of mergers will lead to some organizational conflicts between merged and merging company. This is also easy to see in the airline industry. The most common managerial conflicts are usually happening during organization restructuring. Job rotation is a must and hence force airline employees moving to some distant workplaces. Moreover, the merged airline would easily form a sub-organization against the merging airline. The parties within an organization, or Paixi in Chinese

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translation, has then become one inevitable bi-product of airline merging. Conflicts from different organization culture could also be very serious especially within the merger case of regional niche market carriers. Each of the carrier is a local monopoly in their market, and is adopted to their local environment. Merged to some other carriers is definitely crushing the value system and the market niche of their own.

3. Integration synergies of merger and acquisitions

Whether or not M&A can create better performance on some production and financial indexes are still unknown, but the synergy of airline merging can be examined at the very early stage. Apparently, synergy does exist in some of these airline mergers and acquisitions, especially those cross state cases. For instance, China Airlines of Taiwan acquiring shares of China Cargo Airlines does help China Airlines in expanding their cargo service network to some place they currently cannot reach. Eva Air acquiring Air Macau may possibly create open jaw service routes in across Taiwan Strait, or also extend their service to China through code sharing and 5th freedom. These are all increasing their competition power in the market. On the other hand, less synergy can be found in the local airline M&A in both China and Taiwan.

4. Anti-trust and fair trade issues

The antitrust issue of airline merger and acquisition is always highly concerned by related government bureaus throughout the world. Some famous cases in both Europe and US have indicated one general rule of airline M&A: overlapping markets between merged and merging carriers is harmful to social welfare. This index is always examined with detail. However, airline mergers were encouraged in Taiwan, and the cases were even directed by the government in China. Related bureaus in both places are not able to evaluate these cases but only approve them. Some complaints have already been found during the transition period. Still, this is one important issue left behind these M&A activities.

5. Conclusion: Forming the Greater China Alliance

The airline mergers and acquisitions in the Greater China Area in the past few years has lead to one much more concentrate market in this area. Six major airline groups, including Air China Group, China Eastern Airlines Group, China Southern Airlines Group, Hainan Airlines Group, China Airlines Group, Evergreen Group are established.

Potentially there are two other airline group can be organized, but the total number of airline groups would probably stayed in 6 to 7. If cross border mergers can be more accepted by the modification of aviation regulations in both sides, further integration can still be expected. The interstate transportation demands have successfully made the market between Taiwan and Hong Kong the biggest one in the world. Since Chinese is now controlling the market, cross holding equity in both Hong Kong and Macau by either Taiwan or China could be a possible and acceptable norm. Future M&A across the Taiwan Strait would probably be initiated through the integration of Hong Kong and Macau aviation market.

Whether these mergers and acquisitions are helpful or not to the airlines' operations is still unknown, but the decreasing number of competitors is at least a good news to those survival airlines, especially large scale carriers. In the past few years, Asian financial crisis, post September 11 recession, and recent SARS disease outbreaks have all created considerable operation deficit of some carriers in this area. Less competition may enhance the existing airlines' market power, hence make airline a profitable business in the future. Small carriers can now serve in a niche market only. New route allocation regulations in China have even asked small carriers to withdraw from the hub airports. Taiwan is also giving the rights of trunk line operations to the major carriers only. These changes may also encourage new airline M&A in the future because airliners will seek better stakes in the market. All these happening changes is worth watching. Future studies may focus on these interesting and important facts to find out both the short term and long term effects of M&A. Numerical analysis using some financial or production indexes should also be applied in the future if statistical data finally available.

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The empirical analysis of the impact of alliances on airline operations

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Abstract

Airline alliances are dominating the current air transport industry with the largest carriers of the world belonging to one of the four alliance groupings – "Wings", Star Alliance, oneworld, SkyTeam – which represent 56% of world Revenue Passenger Kilometers. Although much research has been carried out to evaluate the impact of alliance membership on performance of airlines, it would be of interest to ascertain the degree of impact perceived by participating airlines in alliances. It is the purpose of this paper to gather the opinion of all the airlines, belonging to the four global alliance groupings on the impact alliances have had on their traffic and on their performance in general. To achieve this, a comprehensive survey of the alliance management departments of airlines participating in the four global strategic alliances was carried out. With this framework the survey has examined which type of cooperation among carriers (FFP, Code Share, Strategic Alliance without antitrust immunity, Strategic Alliance with antitrust immunity) has produced the most positive impact on traffic and which type of route (short haul, long haul, hub-hub, hub-non hub, non hub-non hub) has been mostly affected. In addition, the respondent airlines quantified the effect alliances have had on specific areas of their operation, such as load factors, traffic, costs, revenue and fares. Their responses have been analysed under each global alliances grouping, under airline and under geographic region to establish which group, type of carrier and geographic region has benefited most. The results show that each of the four global alliances groupings has experienced different results according to the type of collaboration agreed amongst their member airlines.

Keywords: Airline Alliances, Passenger traffic

1.0   Introduction

Alliances are generally a strategy that companies use when the acquisition of another company or internal development as means of growing is not an option. Sometimes even if internal development is possible, alliances are preferable as it provides quicker access to new markets. Alliances vary in degree of commitment from simple marketing cooperation to just short of complete mergers or acquisitions. Globally, mergers and acquisition deals exceeded $2,000 billions in 1999-2000 indicating, companies increasingly embark on partnerships to achieve their expansion goals and develop a world-class capability. According to Harbison and Pekar (1999) survey, in 1997-1999 alone more than 20,000 alliances have been formed worldwide and, interestingly, more than half of them are between competitors.

In this respect, airline industry is not an exception. There has clearly been a surge in formation of alliances amongst airlines in recent years. A large number of airlines have established or joined one of the four global airline alliances: " Wings" (1989)[1], Star Alliance (1997), oneworld (1998), SkyTeam (2000) – and they now control as allied partners 56% of world Revenue Passenger Kilometers (Airline Business, September 2002). See appendix A for the description of each alliances groupings and their memberships.

IATA (2001) defines an "airline alliance" as follows: three or more airlines participating in commercial relationship or joint venture, where (i) a joint and commonly identifiable product is marketed under a single commercial name or brand; and (ii) this commercial name or brand is promoted to the public through the airlines participating in the alliance and its agents; and (iii) the commercial name or brand is used to identify the alliance services at airports and other service delivery points in situations where bilateral agreements exist, e.g. code share agreement.

According to another definition "A strategic airline alliance is a long term partnership of two or more firms who attempt to enhance advantages collectively vis-à-vis their competitors by sharing scarce resources including brand assets and market access capability, enhancing service quality, and thereby improving profitability…a strategic alliance is one involving strategic commitment by top management to link up a substantial part of their respective route networks as well as collaborating on some key areas of airline business."

The majority of airlines are interested to extend their network beyond the markets they currently serve. However, due to regulatory restrictions on market access, ownership and control, they have been pushed towards the formation of strategic

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[1] Date of alliance formation

alliance groupings. Legislation aimed at protecting national interests has meant that it is virtually impossible to acquire a controlling interest in airlines in countries or trading blocks outside those in which an airline is owned and operated. For example, a non-US airline can only have up to a maximum of 25% of voting share in any US carrier. A non-EU carrier can purchase up to a maximum of 49% of an EU carrier. To grow naturally a carrier is also subject to restrictions such as the limitations imposed on its growing in home markets, or the lack of regulatory approval to access foreign markets, or the lack of slots at airports at which the airline wants to operate. In addition to expanding their network, through alliances airlines aim at improve revenues, reduce costs and increase customer benefits.

As a result, as discussed above, in the last decade a number of alliance groupings have emerged. Given such a dynamics in the airline industry and the current crisis due to slow down in the economy and 11th September attack, it was of interest to assess the followings:

- How do airlines perceive the impact of alliances on their operation in general and on passenger traffic in particular?
- How different types of partnership agreements have affected the results?
- Have airlines of different size, operating from different region and belonging to different alliance grouping been affected differently?

2.0 Assessing the perception of airlines about their alliances impact

To address the above questions, a comprehensive survey of the alliance management departments of airlines participating in the four global strategic alliances was carried out in 2002.

The heads of the alliance departments of all airlines – that is 28 carriers at the time this survey – belonging to the alliance groupings of "Wings", Star Alliance, oneworld and SkyTeam were contacted to participate in a questionnaire survey. The questionnaire focused on the impact of the alliances on airlines' operation as this impact is perceived by the heads of the alliance department. All 28 carriers participated in the research giving the survey a 100% response rate.

Special emphasis was given to the impact of alliances on passenger traffic, which is one of the most important factors airlines themselves and airline specialists use to determine airline and alliance performance. In assessing the impact of alliances on passenger traffic the following criteria were taken into account:

- The type of cooperation amongst the carriers themselves (FFP, Code Share, Strategic Alliance with or without antitrust immunity),
- The type of route (hub-hub, hub-non hub, non hub-non hub)
- The global alliance groupings (Wings", Star Alliance, oneworld and SkyTeam)
- The size of carriers measured by their annual output (Available Seat Kilometres-ASK)
- The region where the carriers come from (North America, Europe, Asia, Central and South America).

This was done to establish which type of cooperation, route, alliances groupings, carrier size and geographical region has benefited most, in terms of passenger traffic, as a result of the formation of alliances.

As the questionnaire survey presented a unique opportunity to collect inside information about the impact of airline alliances, the scope of the questions was extended to cover some other specific areas of airline operations that alliances may affect, such as load factors, traffic, revenue, costs and fares. These parameters were chosen since they constitute the measures airlines use to evaluate their performance and thus any carrier entering into an alliance expects to improve such measures. Furthermore, some questions were included to examine whether there has been satisfaction from the participation in the alliance, the degree of satisfaction arising from this participation in the alliances and how fast the impact of alliance on their operation has become evident.

3.0   The general impact of alliances on airlines operation

The findings of survey revealed that one of the key reasons for airlines decision to participate in an alliance has been a defensive move as they expressed the opinion that if an airline remained unaligned, it would be worse off losing traffic to other airlines in alliance groupings. They are also of the opinion that the alliance relationship is very complex and still developing.

In general the accession and participation in the alliances is considered successful. While one third of participants rate their alliance cooperation as "excellent", the rest believe that the course and operation of the alliances has been so far "good". A European regional carrier expressed some reservations and preferred to take a neutral stance.

Almost all participants believe that joining the alliance grouping has led to an increase in traffic, load factor and revenue. While two thirds of participants expressed the

opinion that fares have not been influenced, the rest declared that fares on routes operated jointly by partners have increased. A large proportion of participating airlines affirms that costs have registered some reduction.

Figure 1
Impact of airline alliances
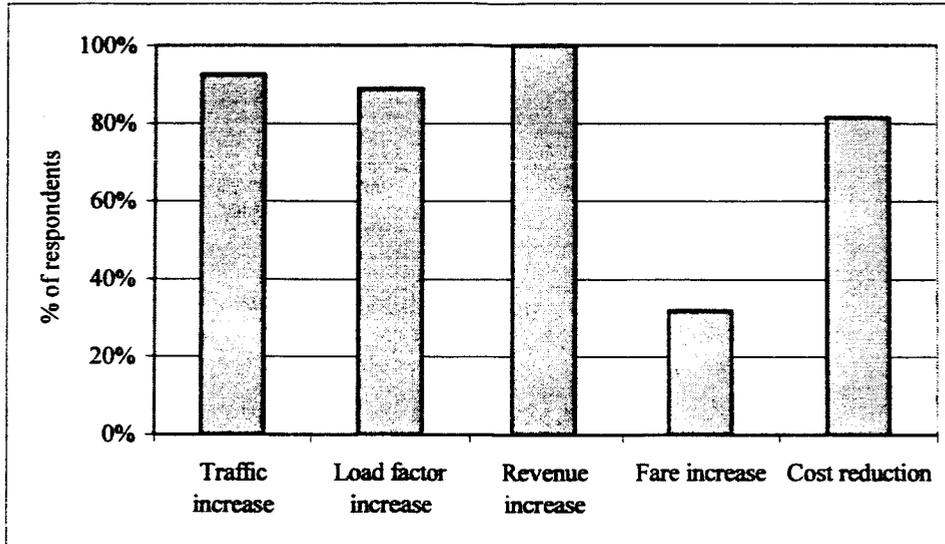
To establish the degree of the impact of alliances on airlines' operation, the respondents were asked to rate the impact from 1 to 5, with 1 referring to "no impact" and 5 to "significant impact". It can be seen from figure 2 that the most pronounced effects have been experienced in the area of passenger traffic. Next in ranking are revenue and loaf factor. The least pronounced impacts have been observed in the areas of costs and fares. As far as costs are concerned, not only airlines have not reaped much benefit from their alliance participation but have entail certain substantial initial expenses such as IT system harmonization, marketing and advertising expenses which could put a serious strain, at least short term, on the airline costs. Any significant long-term cost reductions/synergies require the alignment of some product specifications, a common approach, a common fleet planning and require not only some time and a high degree of integration but also a major commitment on the part of the allies

Figure 2

The degree of alliance impact on airline operations
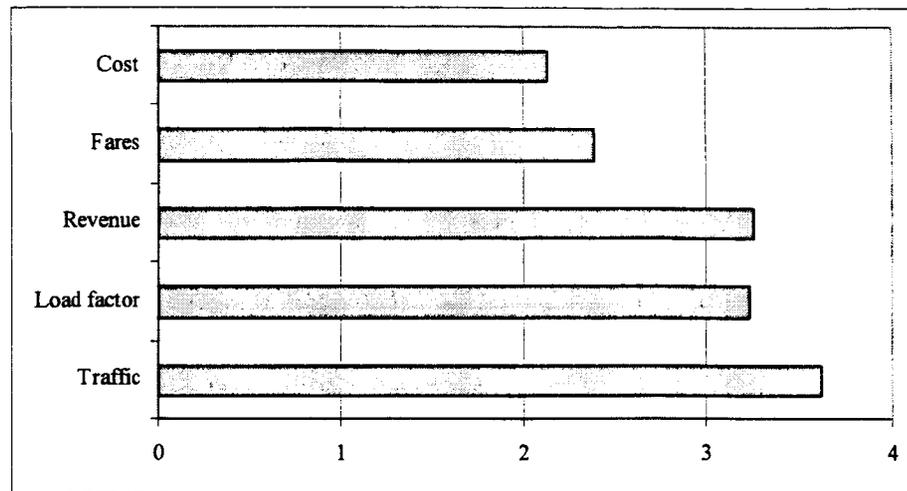
Scale of 1 to 5, 1= no impact and 5=significant impact

The responses relative to fare increases indicate that the reduction in competition due to airline alliances has not led to acute monopolistic situations – as regulators would have acted to prevent such a development. However, what remains rather alarming is the fact that the carriers that take the contrary opinion and claim that there has been an increase in fares amounting to even 10% are amongst the major players in the existing alliances on both sides of the Atlantic. Such fare increases may be related more to the policy an airline follows to deal with decreased profitability than to monopolistic situation. Each airline however, follows the policy that it sees fit even if it contradicts the policy followed by its partners. Lufthansa's strategy after September 2001 was to cut capacity and maintain fare discipline whereas United Airlines' strategy was to cut fares. The dispute between the partners ended up with the German government complaining to the US government. United's choice of policy proved to be rather questionable given that they filed for bankruptcy protection under Chapter 11 (Airline Business, January 2003).

4.0   Impact of airline alliances on passenger traffic

As mentioned in the above section airlines have most benefited from participation in airline alliances in the form of increase in traffic. Almost 90% of respondents claimed that they experienced an increase in traffic between one and two years from the inception of their partnerships with other airlines. Unlike the common belief that airlines attempt to provide a seamless travel have caused the increase in passenger traffic, the respondents believe that the provision of the joint frequent flyer programme has played an important role in an upsurge in traffic. The respondents

believe that the rate of increase in traffic tends to stabilise a few years after the launch of the alliance.

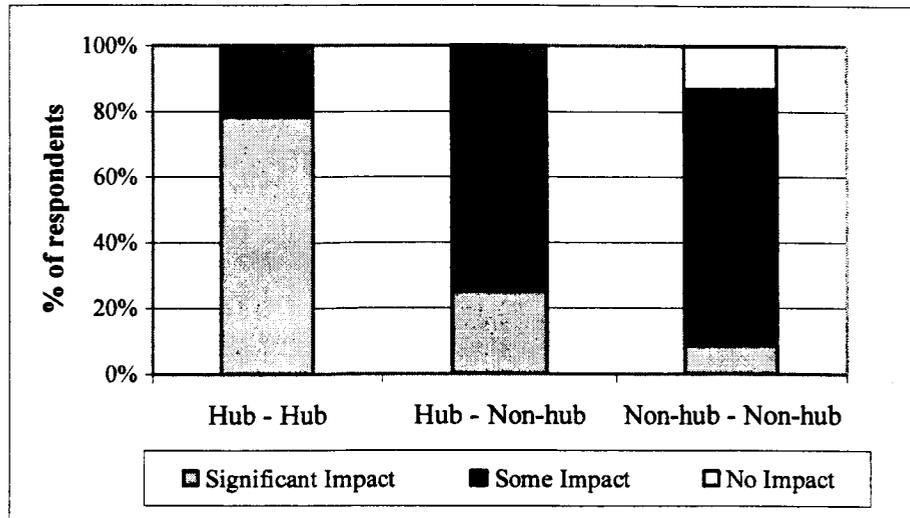## 4.1 The impact of alliance on traffic by route type

The greatest increase in passenger traffic was observed primarily on hub-hub routes, and secondarily on hub-non-hub routes. More specifically, the increase in passenger traffic on the hub-hub routes was assessed as "significant", with 45% of respondents experiencing an increase of more than 16%, while the corresponding percentage increase for hub-non hub routes ranges from 6 to 15% as per 52% of the respondents; as for non hub-non hub routes, all respondents have assessed the traffic increase as moderate, with the percentages equally divided between the 0-5% and the 6-15% brackets. These results seem absolutely reasonable considering that all global carriers, especially the major ones, operate on the hub and spoke system[2] and the whole alliance organisation aims at increasing the hub-hub traffic, especially the high-yielding and efficient transatlantic routes.

International major carriers, including all the American airlines, many of the European and South American carriers claimed that alliances have had a significant impact on their hub-hub. In case of the American and European carriers this is due to the fact that they were the first operators to implement the hub and spoke system. However, Asian carriers claimed a moderate increase in their traffic on their hub-hub routes. This could be due to the possibility that these carriers have not exploited their hubs operation to the same extent as their counterparts in the US and Europe. It must also be born in mind that the US and European partners in most cases have benefited from antitrust immunity[3] which allows them to harmonise their operation more effectively.

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[2] An operational system for deploying aircraft that enables a carrier to increase service options at all airports encompassed by the system. It entails the use of a strategically located airport (the hub) served by more than one airline as a passenger exchange point for flights to and from outlying towns and cities (the spokes or non-hub). With this system flights from numerous points (the spokes) arrive at and then depart from a common point (the hub) within a short time from so that traffic arriving from any given point can connect to flights departing to numerous other points. At the hub airport inbound and outbound schedules, that is the connecting traffic, are coordinated with the aim of producing the most convenient and/or transshipment for passengers.

[3] Antitrust immunity from US antitrust laws enables partner airlines to make joint decisions on pricing, scheduling, capacity provision and service quality. Without such immunity airline alliances would be very restricted in terms of what aspects of their business they could jointly undertake

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Figure 3

Alliance impact on the traffic by route type

4.2 The impact of alliance on traffic by type of cooperation

It was revealing that among the chosen types of cooperation, that is FFP, Code Share, Strategic Alliance with antitrust immunity and Strategic Alliance without antitrust immunity, it is Code Sharing and Strategic airline Alliances with antitrust immunity that seem to be regarded as the most efficient form of cooperation by the airlines themselves without certainly disregarding the significance and contribution of the other two. Several respondents also stressed that the impact of antitrust immunity is just beginning to unfold but they consider it as a very important element as it provides airlines with ability and flexibility and possibility to coordinate their activities in scheduling and pricing. A very small number of Asian carriers believe that strategic alliances have no impact on traffic. This can be attributed to the fact that Strategic Alliances are evolving in a risky and uncertain environment in which airlines are demanded to make a commitment without being certain of the future evolution of the alliance.

Figure 4
Impact of type of airline cooperation on traffic
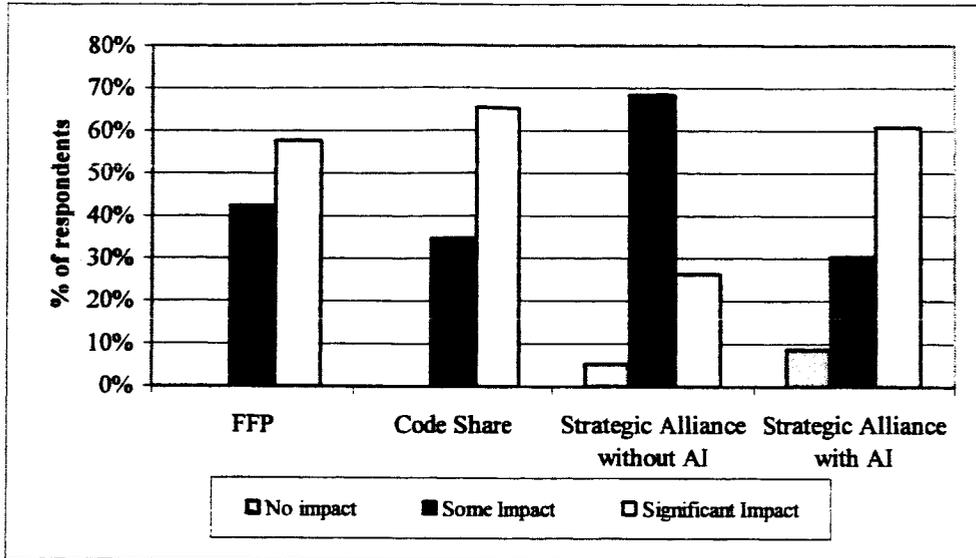
The provision of joint FFP is considered very effective in boosting traffic. The joint scheme should enable members to collect and redeem points or miles on any one of the partner airlines. It would also allow the recognition of elite status by a greater number of member airlines, as opposed to just the one airline to which the qualified passenger belongs. Most of the times FFP and Code Sharing co-exist and constitute a much more common form of cooperation than Strategic Alliances whether with antitrust immunity or without antitrust immunity.

4.3 The impact of alliance on traffic by alliance groupings

The SkyTeam members seemed to be the most satisfied from the alliance performance followed by the Star Alliance members. No member of the oneworld alliance has rated their alliance cooperation as "excellent" and it has the only carrier that has taken a neutral attitude towards alliances. This is probably due to the lack of deeper cooperation among the members. This by alliance comparative review points out that antitrust immunity is a major parameter for the success of an alliance as far as traffic is concerned.

Almost all members in the SkyTeam and "Wings" believe that the most increase in traffic has taken place on their hub-hub routes where as the corresponding percentage for oneworld and Star Alliance is 50% and 80% respectively. "Wings" has experienced the highest increase on its hub-non hub routes. It must be born in mind that "Wings" is made up of only two carriers, therefore it is difficult to compare it with the other alliances whose membership ranges from 6 to 13 members.

Figure 5

The alliance impact on traffic by alliance groupings
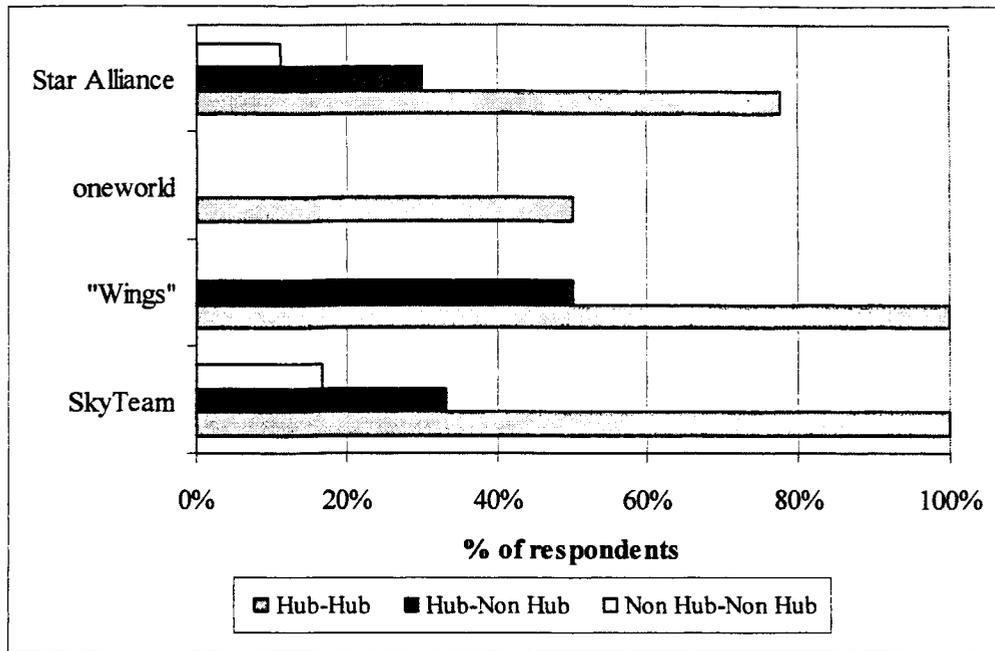
"Wings" appears to have experienced the most positive impact in all aspects of their operations. SkyTeam has benefited greatly from increase in traffic and revenue; the increase in revenue may be attributed to the deeper cooperation existing among the partners of this alliance.

Table 1

Impact of alliances on airlines operations by alliance groupings

	SkyTeam	"Wings"	oneworld	Star Alliance
Traffic	3.8	5.0	3.5	3.3
Load factor	3.3	4.5	3.0	3.1
Revenue	3.8	4.5	2.7	3.0
Fare increases	2.0	3.5	1.8	2.1
Cost reductions	2.0	3.0	2.8	2.3

Scale of 1 to 5, 1= no impact and 5=significant impact

4.4 The impact of alliance on traffic by airline size

Large airlines, in general, seem to be satisfied with their alliance cooperation, however with some reservations. While two thirds stated that their partnership with other airlines is "good" only one third viewed it as "excellent". The majority experienced the increase in traffic in the first year of launching their partnership. Almost half of the large carriers have experienced up to 5% increase in traffic. The

increase in traffic has largely taken place for these carriers on hub to hub routes. They believe Code Sharing and Strategic Alliance with antitrust immunity have a significant impact on traffic, scoring them as 4.3 and 4.5 respectively on a scale of 1 to 5.

While medium size airlines are generally satisfied with their alliance cooperation, small carriers have some reservation about their relationship with their partners. This could be due to their influence on the decision making within the alliance groupings. The medium and small carriers have also benefited from an increase in traffic due to formation of alliances but it has taken them longer – up to two years – to experience the rise in traffic. A large proportion has experienced up to 15% increase in traffic. This could be due to the fact that their base traffic is smaller than that of the larger carriers. It is interesting to note that medium and small carriers believe frequent flyer programme cooperation and Code Sharing have had a significant impact on their traffic. Clearly small and medium sized carriers benefit more by joining the large airline frequent flyer programmes.

Figure 6
The impact of the different alliance cooperation types on traffic by airline size
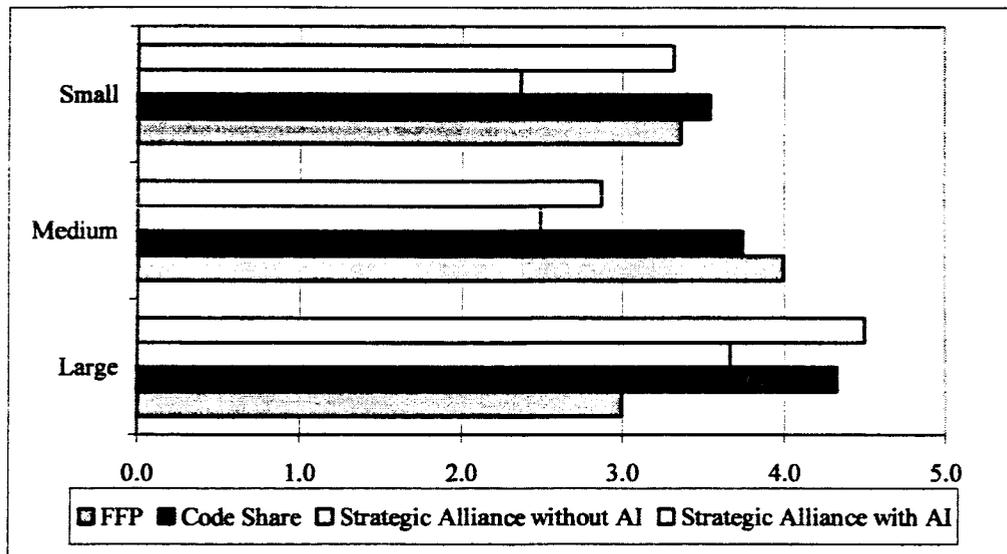
Scale of 1 to 5, 1= no impact and 5=significant impact

4.5 The impact of alliance on traffic by region

The analysis of the responses indicates that Central and South America have experienced the greatest increases in traffic, load factors and revenues as a result of alliances. It should be noted though that three out of the four carriers of this region entered alliances very recently and may be experiencing the initial positive alliance

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effects. This is the reason also why half of the carriers from this region – the highest percentage among all regions – characterize alliances as "excellent". The greatest increase in fares has been registered in Asia, whereas as far as costs are concerned it is European carries that report the most significant decrease, since the carriers of this region are among those that feel more pressingly the need to reduce costs. As it was expected, it is the North American airlines followed by the European ones that have experienced the most significant positive impact from antitrust immunity since it is they that have the majority of these exemptions.

Figure 7

Alliance impact on traffic according to geographical region
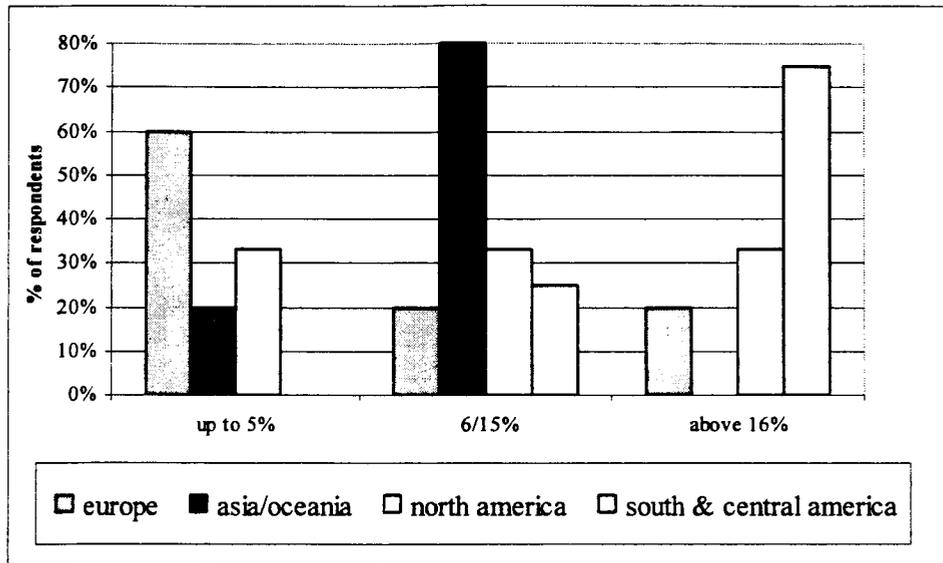
The above figure depicts how the carriers of the different geographical regions. The above figure depicts how the carriers of the different geographical regions estimate the impact of the alliances they participate to on their traffic. It is the Central and South American carriers that seem to have experienced the greatest increase in traffic, which can be explained both by the fact that it is the area that is undergoing the greatest increase in traffic and by the fact that these carriers had a rather limited network before the establishment of the alliances. No airline of this region has recorded an increase lower than 6%. Asia and Oceania is the region that has stated the second greatest increase in traffic, with the majority of carriers stating an increase in traffic ranging from 6 to 15%. This geographic region includes many developing countries and has organized in these last years many important athletic events. European carriers have declared the lowest increase since the carriers from this region had before the formation of the alliances an extensive network and numerous connections with all the other geographical regions of the world.

Exception to this general trend were the North American and European carriers, such as the members of "Wings" (Northwest Airlines and KLM) which have been cooperating within this framework for many years and for these carriers Strategic Alliance with antitrust immunity is very important. On the contrary, Asian carriers consider FFP as the most important factor given that their Code Sharing agreements and Strategic Alliances are much more difficult to operate because of regulatory restrictions.

Conclusion

The overall substantial conclusion is that alliances, despite the form of cooperation chosen and established among the partners, entail numerous benefits for the airlines and certainly do come up to the initial expectations. Alliances bring about an increase in passenger traffic with a parallel increase in load factors and some reduction in costs. Thus, a clear improvement of revenue is observed, a fact resulting from the combination of the increase in traffic and the decrease in costs. Fares, on the contrary, do not move along the same course since in certain cases there is an increase and in others there is no increase.

The questionnaire analysis indicates that both passenger traffic and load factors of all airlines show clear increase. This in return has positively impacted on revenue, while the impact on costs, even though positive, remains comparatively limited at least on a short-term basis. The impact on passenger traffic is relatively substantial and has been experienced from one to two years since the inception of alliance cooperation. The increase in traffic has mostly been experienced on hub-hub routes. As regards the impact on fares, the situation remains rather hazy, since the majority of airlines have given ambiguous answers when asked to state whether there has been increase or decrease of fares.

The greatest benefits from alliances result from the more advanced and integrated forms of cooperation, just as the one that links the carries of the "Wings" alliance, which is characterised by the existence of antitrust immunity and the establishment of a joint venture. Most alliances however, remain "strategic" only in name, at least at their present stage, basing their cooperation on Code Share and FFP coordination and have not proceeded to deeper integration.

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Appendix A

Description of airline alliances

"Wings"

"Wings" is the non-official name for the alliance of KLM, Northwest Airlines and Continental Airlines. KLM and Northwest have had a far reaching alliance agreement since 1989, with common branding, purchasing, management, marketing and FFP, although an equity stake that KLM had in Northwest was sold after disagreement of control of Northwest. In 1999 Northwest Airlines bought a stake in Continental Airlines, and announced co-operation including code sharing and frequent flyer participation. In 1998, KLM and Alitalia concluded an alliance agreement, setting up passenger and cargo joint ventures to manage the airlines operations and marketing but the agreement was dismantled in August 2000. KLM and Northwest received antitrust immunity from the US DOT in November 1993.

Star Alliance

Star Alliance was launched in May 1997, by Air Canada, Lufthansa, SAS, Thai and United airlines to create a global airline network. Varig joined the alliance in October 1997, with Ansett Australia and Air New Zealand in March 1999. Ansett subsequently left as it ceased operations in March 2002. All Nippon Airways joined the Star Alliance in October 1999, Austrian Airlines Group including Lauda Air and Tyrolean Airways joined in March 2000 and Singapore Airlines in April 2000. British Midland and Mexicana joined in July 2000. Star Alliance has a total of almost 2000 aircraft, serves around 800 destinations in 130 countries worldwide and transports more than a quarter of a billion passengers annually, through extensive code share agreements, with 'round the world' fares for global travellers. The alliance allows access to over 500 Star Alliance lounges around the world, reciprocal FFPs, through check-in, streamlined airport operations, cargo co-operation, joint purchasing, advertising and promotions. US Airways will join the alliance as United Airlines has come up serious financial problems. Lufthansa/UA alliance has received antitrust immunity from the US DOT.

oneworld

A global marketing alliance announced in September 1998. American Airlines, British Airways, Canadian, Cathay Pacific, Finnair, Iberia and Qantas offer closer linking of FFPs, reciprocal access to airport lounges, smoother transfers between carriers and a range of global products including 'oneworld Explorer' fares. After the takeover by Air Canada, Canadian Airlines left oneworld on June 1, 2000, while Lan Chile and Aer Lingus joined on the same date.

SkyTeam

It is the most recent global alliance. Formed in 1999 by Air France and Delta Air Lines, it has extended its reach with Aeromexico and Korean Air as well as Czech carrier CSA in October 2000 while Alitalia joined in July 2001. With a marketing focus on passenger service, that is, code sharing, joint marketing and reciprocal frequent flyer programs, its strategy is based on market synergies and the growth potential of Paris-CDG as a connection platform. Cargo cooperation is also part of the alliance. SkyTeam is expanding and currently offers nearly 7,100 flights to more than 470 destinations. It also has 289 reception lounges.

The global alliance groupings – traffic/revenue totals and world market share

	Passenger traffic (RPK)		Passenger numbers		Group revenues	
	Billion	share	million	share	$ billion	share
"Wings"	176	6,0%	70,1	4,3%	16	4,5%
Star Alliance	637	21,7%	279,2	17,2%	70	20,0%
oneworld	471	16,1%	198	12,2%	46	13,2%
SkyTeam	352	12,0%	207,4	12,8%	37	10,5%
Total Alliances	1636	55,8%	754,7	46,5%	169	48,2%

Source: Airline Business (September 2002)

Alliances and their members

"Wings"

	Date joined	Region
KLM	Jun-89	Europe
Northwest Airlines	Jun-89	North America

Star Alliance

	Date joined	Region
Air Canada	May-97	North America
Air New Zealand	Mar-99	Oceania/Asia
ANA	Oct-99	Oceania/Asia
Asiana	Mar-03	Oceania/Asia
Austrian	Mar-00	Europe
bmi british midland	Jul-00	Europe
Lufthansa	May-97	Europe
Mexicana	Jul-99	Central and South America
SAS	May-97	Europe
Singapore	Apr-00	Oceania/Asia
Spanair	Mar-03	Europe

Thai Airways	May-97	Oceania/Asia
United Airlines	May-97	North America
Varig	Oct-97	Central and South America

oneworld

	Date joined	Region
Aer Lingus	Jun-00	Europe
American Airlines	Sep-98	North America
British Airways	Sep-98	Europe
Cathay Pacific	Sep-98	Oceania/Asia
Finnair	Sep-99	Europe
Iberia	Sep-99	Europe
LanChile	Jun-00	Central and South America
Qantas Airways	Sep-98	Oceania/Asia

SkyTeam

	Date joined	Region
Aeromexico	Sep-99	Central and South America
Air France	Sep-99	Europe
Alitalia	Jul-01	Europe
CSA Czech Airlines	Mar-01	Europe
Delta Air Lines	Sep-99	North America
Korean Air	Jul-00	Oceania/Asia

Source: Airline Business (September 2002)

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The Economics of Airport Congestion Pricing

Paper for the The 7ᵗʰ ATRS World Conference
First Draft: do not quote without contacting the authors

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1   INTRODUCTION

Many airports are facing capacity problems. In the U.S., 25 airports are classified as "severely congested" by the Federal Aviation Administration (Daniel, 2001), while also in Europe many airports face congestion problems (e.g. London Heathrow, Frankfurt and Amsterdam Schiphol).

In the U.S., the (runway) capacity of (larger) airports is usually allocated based on a first-come first-served principle. When capacity is limited, arriving aircraft cause delays (and thus costs) for other arriving aircraft. Only four US airports (Washington Ronald Reagan, New York LaGuardia, New York Kennedy and Chicago O'Hare) are slot-constrained; slot trading between airlines is allowed at these airports (see e.g Starkie, 1992). European airports are usually slot-constrained; slots are allocated by a slot coordinator. The slot-allocation mechanism at most airports is economically inefficient. The users of capacity (airlines) may pay less than the marginal social cost (congestion costs are not paid, entry is deterred), and are not necessarily the (potential) users that attach the highest economic value to the capacity.

Airport congestion pricing also to allocate scarce capacity to those parties that attach the highest economic value to it. Most studies of (second-best) congestion pricing in transport

networks concern road traffic and consider link-based tolls. For other modes, however, it may often be nodes, rather than the links between them, that form the bottlenecks in a network. A question that naturally arises is whether insights from studies on link-based pricing are directly transferable to node-based pricing, especially under second-best circumstances where multiple market distortions exist simultaneously. It may be expected that the nature of other market distortions, additional to congestion externalities, will often be different at nodes than along links. Given the substantial and growing congestion at major airports and other transport hubs and nodes throughout the world, it seems highly relevant to investigate the implications for airport congestion pricing.

The economic nature of airports and their primary user(s) may indeed imply important deviations from the economic conditions governing a congested road network. In particular, individual road users would typically not have any market power, and can thus be assumed to take travel times and tolls (if any) as given (in practice, this would normally also hold for transport firms that may have multiple trucks using the same congested network simultaneously). Airports, in contrast, and especially the more congested hubs, will typically have spatial monopolistic power, while the primary user(s), airports, will often compete under oligopolistic conditions. Moreover, when positive network externalities (or economies of density) induce these airlines to use hub-and-spoke type networks, with different airlines using different hubs, these oligopolies may be asymmetric. A substantial share of congestion costs may then in fact not be external effects, but internal instead, in the sense that the travel delays imposed by one service upon other services would often concern services of that same operator, who can be assumed to take these firm internal congestion effects already into account when designing a profit-maximizing price and frequency schedule for the hub (Brueckner, 2002).

A further implication of oligopolistic competition would be that another distortion, besides congestion, is likely to be present, namely that of strategic interaction between competitors with the result of non-competitive pricing. Absent congestion, consumer prices may then exceed marginal costs, implying that an economic argument for subsidization rather than taxation would exist. As pointed out by Buchanan (1969) and Baumol and Oates (1988) in the context of a polluting monopolistic firm, the implication for Pigouvian externality pricing is that the second-best optimal tax would be below the marginal external costs and may even become negative. This would provide a second argument, in addition to the point raised by Brueckner (2002), of why optimal congestion charges at a hub would be below

marginal external congestion costs if straightforwardly defined as the value of a single service's marginal delay costs for all other services.

This paper aims to investigate such issues in a network environment, by developing a model that is cast in terms of aviation and considers second-best congestion pricing for incoming and outgoing flights at airports. The model extends an earlier model of second-best pricing in congested road networks (Verhoef, 2002). The second-best circumstances under which congestion tolls have to be set are those just mentioned. We consider a simple network with multiple nodes, where both airlines and passengers suffer from congestion at airports. Three types of interacting players are present in our model: a regulatory authority, airlines, and passengers; each having their own objective. Congestion tolls can be determined by a single regulator for all airports in the network, but also by "local" regulators of specific airports. "Competition" between local regulators then becomes an issue. The insights developed may of course often carry over directly to congestion pricing at nodes for different modes than aviation, and possibly even different types of networks, provided market conditions are similar to those considered here.

Airport congestion pricing has already received some attention in the literature. Carlin and Park (1970) estimated the external cost of a peak-period landing at LaGuardia was $2000 (in 1969 $); about twenty times the actual landing fee, although this number should not be interpreted as an equilibrium congestion toll. Oum and Zhang (1990) examine the relation between congestion tolls and capacity costs, and find that when capacity investment is lumpy, the cost recovery theorem (which states that congestion toll revenues just cover amortized capacity (expansion) costs under constant returns to scale) no longer holds. Daniel (1995, 2001) combines stochastic queuing theory with a Vickrey-type bottleneck model, and simulation results show that congestion pricing causes a redistribution of flights over the day, where smaller aircraft may divert to other airports because they value their use less than the social cost of using the congested airport. Brueckner (2002) analyzes airport congestion pricing when airlines are nonatomistic, and concludes that there may be only a limited or even no role for congestion pricing when the number of airlines using the node decreases, as the share of internalized congestion costs increases. Brueckner (2003) analyzes airport congestion pricing in a network setting, and finds that the airline specific toll equals (one minus an airline's flight share) multiplied by the congestion damage caused by the airline.

The structure of the paper is as follows. First, the notation and assumptions will be presented in Section 2. Section 3 contains the (profit) maximization model for the network

operators (airlines). Section 4 contains the regulator's optimization problem. Section 5 presents a simple numerical solution, and Section 6 concludes.

2 NOTATION AND ASSUMPTIONS

In the model, we distinguish three different parties. *Passengers* wish to travel between an origin and destination (a formulation with freight transport with atomistic demanders would be comparable to the one given here). In order to do so, services of an *airline* are necessary. Airlines, in turn, need the services of two (origin and destination) or more (in case of indirect services) airports. Prices for the use of the airport may be set by a profit maximizing *airport operator* or a welfare maximizing *regulatory authority*. Because we are concerned with (second-best) optimal airport prices, we will be considering a regulatory authority alone. An extension of the model to four types of players (regulators, airport operators, airlines and passengers) is considered as an interesting option for future work.

For the general specification of the model, a number of assumptions are made that will now be presented.

Assumption 1. A given passenger's trip in an origin- destination j pair will involve one airline only. The inverse demand function in each market is linear in form:

$$D_j\left(\sum_{i=1}^{I} q_{i,j}\right) = \alpha_j - \beta_j \sum_{i=1}^{I} q_{i,j} \tag{1}$$

where α_j and $\beta_j > 0$; α_j represents the maximum gross valuation by consumers in market j; $q_{i,j}$ is the number of passengers transported by airline i in market j, and β_j is the demand sensitivity parameter. A linear form is convenient in the numerical version of the model; for the analytical exposition it saves somewhat on the notation as the slope β_j is constant.

Assumption 2. Frequency on a link is

$$f_{i,k} = \frac{1}{\lambda_i} \sum_{j=1}^{J} \delta_{i,j,k} q_{i,j} \tag{2}$$

where $\delta_{i,j,k}$ is a dummy equal to 1 if link k is used in market j by operator i and λ_i is the product of the load factor and the seat capacity. Congestion occurs at nodes only (*i.e.*, not on

links; "capacity in the air" or the capacity of the air traffic control system is abundant). The average congestion costs per passenger or per flight (measured in additional travel time) at node h are assumed to increase linearly with the total frequency at the node:

$$\phi_h = \eta_h \sum_{k=1}^{K} \sum_{i=1}^{I} \delta_{k,h} f_{i,k} = \eta_h \sum_{k=1}^{K} \sum_{i=1}^{I} \delta_{k,h} \frac{1}{\lambda_i} \sum_{j=1}^{J} \delta_{i,j,k} q_{i,j} \tag{3}$$

where η_h is the constant slope of the congestion function and $\delta_{k,h}$ indicates the nodes used on links h. Note that arriving and departing movements need not contribute equally to, and suffer equally from congestion. However, as we only consider return markets, we do not have to make this distinction. The congestion term (in time units) to be included in the passengers' generalized cost function for alternative i in market j then is

$$\phi_{i,j} = \sum_{k=1}^{K} \sum_{h=1}^{H} \delta_{k,h} \delta_{i,j,k} \phi_h \tag{4}$$

where $\delta_{i,j,k}$ denotes the links used in market j and ϕ_h the congestion (measured in time) suffered at these nodes. Multiplying this term by the passengers' value of time yields the monetized congestion delay cost to passengers. Likewise, the term to be included in the airline cost function (over all flights, using link k, to passengers) is:

$$\phi_{i,k} = \sum_{j=1}^{J} \sum_{h=1}^{H} \delta_{k,h} \delta_{i,j,k} \phi_h \tag{5}$$

Assumption 3. The different alternatives i in market j are characterized by a generalized user cost function $g_{i,j}(p_{i,j}, vot_p \times \phi_{i,j})$ where $vot_p \times \phi_{i,j}$ represents the monetized average congestion costs per passenger (vot_p is the passenger's value of time) and $p_{i,j}$ is the fare. The generalized user cost function is linearly additive in form:

$$g_{i,j} = p_{i,j} + vot_p \times \phi_{i,j} \tag{6}$$

Assumption 4. The operator's cost per passenger $c_{i,k}^q$ and per transport movement $c_{i,k}^f$ are constant on each link. t_h is the congestion toll at node h. Total operating costs for operator i are then:

$$\sum_{k=1}^{K} \left(f_{i,k} \left(c_{i,k}^f + \sum_{h=1}^{H} \delta_{k,h} t_h + vot_i \times \phi_{i,k} \right) + c_{i,k}^q \sum_{j=1}^{J} \delta_{i,j,k} q_{i,j} - F_{i,k} \right) \tag{7}$$

which may be rewritten as:

$$\sum_{k=1}^{K} \left(\left[\sum_{m=1}^{J} \delta_{i,m,k} q_{i,m} \right] \times \left[\frac{1}{\lambda_i} \left(c_{i,k}^f + \sum_{h=1}^{H} \delta_{i,k,h} t_h + vot_i \times \phi_{i,k} \right) + c_{i,k}^q \right] - F_{i,k} \right) \qquad (7')$$

where $vot_i \times \phi_{i,k}$ represents the monetized average congestion costs per flight (vot_i is the airline's value of time). $F_{i,k}$ is airline i's fixed cost per link.

Assumption 5. Competing airlines on a specific market act as Cournot opligopolists (*i.e.* they choose an optimal output (and frequency) taking the others' outputs as given). Airlines do not believe that by their actions, they can affect the regulator's tolls (*i.e.* regulators and airlines are playing a Stackelberg type game, the regulators being the leader). Passengers are pure price takers.

Although these assumptions may seem restrictive, many of these assumptions are quite common in the aviation economics literature. The functional form of the cost function used in this paper is similar to the one used by Brueckner and Spiller (1991)[1]. Combined with a linear demand curve, the "Brueckner-Spiller" model has been used regularly in the literature to analyze aviation networks. Despite the conceptual simplicity (but, in case of large networks, computational complexity), recent trends in the aviation markets can easily be explained using this model; see e.g. Brueckner (2001) for an analysis of airline alliances, and Pels *et al.* (2001) for an analysis of optimal airline networks[2]. It is not the objective of this paper to calculate exact tolls for existing airports, for which these assumptions would clearly be too restrictive. This paper aims to develop theoretical insights into the consequences of airport congestion pricing, for which these assumptions suffice.

3   THE SYMMETRIC EQUILIBRIUM

With these assumptions, we can now turn to the derivation of optimal tolls. There are three types of players in the model (passengers, airlines and regulatory authorities), each with their own maximization problem. The model is solved in three steps. First, a passenger demand function for network operator i in market j is determined. Then, using this demand function, the airline problem is specified, and the associated profit maximizing optimality conditions

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[1] Brueckner and Spiller (1991) do not include congestion in their cost function.
[2] See Brueckner (2001) for additional references.

are derived. Finally, the regulator's problem is solved, again using the passenger demand function, and also using the operator optimality conditions as restrictions.

To determine the equilibrium, we focus on a simple network with two airports and two airlines offering services in one market only (see Figure 1). For convenience, we assume that both airlines use aircraft of similar capacity and that marginal costs per passenger (flight) are the same for both airlines. Although this assumption is not necessary to determine the equilibrium, it greatly reduces the notation. These assumptions are relaxed in a numerical exercise.

Figure 1   *Network configuration*

In this network, congestion tolls are the same for both airports (due to symmetry). Moreover, The congestion toll cannot be distinguished from the subsidy necessary to encounter the market-power effect. Hence, only a toll *t* appears in the airline cost functions.

The passenger optimization problem

The maximum willingness to pay for the marginal passenger in market *j* for alternative *i*, including monetized time costs, is given by equation (1) while each passenger's generalized user cost for the use of operator *i* are given by $g_{i,j}(\cdot)$ as defined in equation (6). Intra-marginal passengers' net benefits are determined according to the familiar Marshallian surplus. According to Wardrop's equilibrium conditions, marginal benefits are equal to the average generalized costs in equilibrium (or marginal net benefits are zero) for all used alternatives (operators in this case), so that $D_j(..)=g_{i,j}(..)$ ∀ *i* in equilibrium, while the average generalized costs of unused alternatives cannot be lower than $D_j(..)$ and will typically be higher. Because operators incur costs for a service also when $q_{i,j}=0$ (see (7)), unused alternatives in our model will not actually be offered. By assumption, demand and generalized cost functions are linear, so that the equilibrium condition for both airlines in the simple network implies:

$$p_1 = \alpha - \beta(q_1 + q_2) - 2\eta_h vot_p \frac{q_1 + q_2}{\lambda}$$

$$p_2 = \alpha - \beta(q_1 + q_2) - 2\eta_h vot_p \frac{q_1 + q_2}{\lambda}$$

(8)

where α is the constant in the inverse demand function and β is the slope of the inverse demand function. This operator specific inverse demand curve incorporates passengers' optimizing behavior, and is used in the next step to maximize operator profits. Note that the arguments of this inverse demand function include the quantities sold by competing airline.

The transport network operator maximization problem

As stated in assumption 5, we assume Cournot behavior in modeling airline competition. This is motivated by earlier (empirical) research.[3] In a Cournot oligopoly, excess profits can be made when the number of suppliers is finite. For the alternative of Bertrand-competition, equilibrium prices would equal marginal costs without collusion, when marginal costs are constant (as they are in this model). The current financial problems of many airlines does not mean that Cournot oligopoly modeling would not be appropriate for this sector. High fixed costs may contribute to financial problems, also under Cournot-competition.

Thus, the operators in this model maximize profits with respect to $q_{i,j}$, taking the competitors quantities as given (note that the assumption of a fixed passenger load implies that maximization with respect to frequencies independent of passenger numbers is neither possible nor necessary). In general, the maximization problem for operator i is:

$$\max_{q_i} \pi_i = \left[\alpha - \beta(q_1 + q_2) - 2vot_p \eta_h \frac{q_1 + q_2}{\lambda} \right] q_i - q_i \left[\frac{c^f + 2t + 2vot_i \eta_h \frac{q_1 + q_2}{\lambda}}{\lambda} + c^q \right] - F \quad (9)$$

The first-order necessary conditions for $i=(1,2)$ are:

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[3] For instance, in an empirical analysis of Chicago-based airline routes involving American Airlines and United Airlines, Oum et al. (1993) conclude that "the overall results indicate that the duopolists' conduct may be described as somewhere between Bertrand and Cournot behavior, but much closer to Cournot, in the majority of the sample observations". Brander and Zhang (1990), using similar data, find " strong evidence ... against the highly competitive Bertrand hypothesis". Brander and Zhang (1990) find Cournot behavior plausible for the markets under consideration (Chicago-based routes where American Airlines and United Airlines together have a market share exceeding 75%). Based on these observations, we assume Cournot competition.

$$\alpha - \beta(q_1 + q_2) - 2vot_p\eta_h \frac{q_1 + q_2}{\lambda} - q_i\left(\beta + \frac{2vot_p\eta_h}{\lambda}\right) -$$

$$\left[\frac{c^f + 2t + 2vot_t\eta_h \frac{q_1 + q_2}{\lambda}}{\lambda} + c^q\right] - q_i \frac{2vot_t\eta_h}{\lambda^2} = 0 \tag{10}$$

Each additional passenger transported by airline i causes a congestion cost $2\eta_h vot_t / \lambda^2$ for both airline i and airline $-i$. Likewise, a congestion cost of $2\eta_h vot_p / \lambda$ is imposed on the passengers transported by both airline i and airline $-i$. From the first-order condition for profit maximization, it is apparent that airline i only internalizes the congestion incurred by itself or its passengers (the last LHS-term and the fourth LHS-term respectively). Because the airlines have the same outputs in the symmetric equilibrium, it follows that the airlines internalize half of the congestion they are responsible for (the same result is obtained by Brueckner, 2003). Solving the first-order conditions yields the following optimal outputs:

$$q_1 = q_2 = \frac{1}{3} \frac{\lambda[\alpha\lambda - 2t - c^f - \lambda c^q]}{\beta\lambda^2 + 2\eta(\lambda vot_p + vot_t)} \tag{11}$$

which are positive when

$$\alpha > \frac{2t + c^f + \lambda c^q}{\lambda_t} \tag{12}$$

The latter condition simply states that outputs are positive when the passengers' gross valuation of an airline service exceeds the average cost of the service.

From the first-order condition and the generalized cost function, we can derive the fare:

$$p_i = \left[\frac{1}{\lambda}\left(c_i^f + 2t + 2vot_t\eta_h \frac{q_1 + q_2}{\lambda}\right) + c^q\right] + q_i\left(\beta + \frac{2vot_p\eta_h}{\lambda} + \frac{2vot_t\eta_h}{\lambda^2}\right), \quad \forall i = 1,2 \tag{13}$$

The first RHS-term (in square brackets) is the airline's operating cost per passenger. The second RHS-term consists of a mark-up over the marginal costs of i) $q_i(2\eta_h/\lambda)(vot_p + vot_i/\lambda)$ reflecting internalization of congestion costs and ii) $q_i\beta$ reflecting "residual" market power. Because airlines have market power, they are able to internalize congestion. But there is a "residual" market power effect which causes fare to exceed the welfare maximizing fare.

By construction, $p_1=p_2$, so that the fare is (after substituting the optimal values for the qs):

$$ p = \frac{\beta\lambda^2\left(\alpha + c_1^q + c_2^q\right) + \left[\beta\left(c_1^l + c_2^l + 4t\right)\right]\lambda + 2\eta_h\left\{\alpha + \left(c_1^q + c_2^q\right)\right\}vot_p\lambda + 3\alpha vot_k + vot_p\left(4t + c_1^l + c_2^l\right)\right\}}{\beta\lambda^2 + 2\lambda vot_p + 2vot_l} $$

(14)

It follows from (14) that the equilibrium value for $q_{i,j}$ is a function of the toll t_h if $\delta_{k,h}=1$. The optimal toll is determined by the regulator.

The regulator's maximization problem

From the analysis in the preceding subsection, it is clear that there is large congestion effect that is not internalized by the carriers. In this section, we formulate strategies for a regulator to "fix" problem.

In terms of objectives, we consider welfare-maximizing regulation. Since there is a market-power effect, which, considered in isolation, requires a subsidy, the resulting optimal toll may be negative. Because both airlines have the same operating characteristics, and demand is shared evenly between the carriers, a regulator will set only one toll; this toll is paid by both airlines for both the usage of both airports. In the asymmetric equilibrium, differentiated tolls $t_{h,i}$ are necessary. Moreover, in networks with more than two nodes, it has to be acknowledged that congestion occurs at the airport level, while market power occurs at the market-level.

The global regulator maximizes surplus for the entire network: the regulator considers consumer surplus in *all* markets and profits of *all* operators. It sets a common toll t for all nodes h in the system. The authority thus maximizes the following objective function:

which is necessarily positive when $q{>}0$ (i.e. when (12) holds). Likewise, the subsidy necessary to encounter the market power effect is:

$$s = -\frac{\beta\lambda^2}{3}\frac{\left(\alpha\lambda - c^q\lambda - c^f\right)}{\beta\lambda^2 + 2\eta\left(\lambda vot_p + vot_l\right)}$$ (19)

The subsidy would be given on a market level, while the toll would be levied at the airport level (and both are carrier-specific). In the symmetric equilibrium for a network with only market, one can not distinguish between airport and market specific tolls, because both depend on the passenger flow in a single market.

A welfare maximizing regulator will thus set a toll

$$t = t^c + s = \frac{1}{3}\frac{\left(2\eta_h\left(\lambda vot_p + vot_k\right) - \beta\lambda^2\right)\left[\alpha\lambda - c^l - \lambda c^q\right]}{\beta\lambda^2 + 2\eta\left(\lambda vot_p + vot_l\right)}$$ (20)

Condition (12) for positive qs implies that $\alpha > \left(c^l + \lambda c_2^q\right)/\lambda$, so that the second term in the numerator is positive. The toll is negative when $2\eta_h\left(\lambda vot_p + vot_l\right) - \beta\lambda^2 < 0$; i.e. when the "residual" market power effect $q_i\beta$ in the fare-equation (13) is larger than the congestion effect $q_i(2\eta_h/\lambda)(vot_p + vot_l/\lambda)$. Since subsidization may not be feasible in practice, so that the regulator may set a congestion toll only, as in (18). Note that this toll will not maximize welfare. In fact, to maximize welfare, output should be increased (because the market power effect dominates), while output is decreased by the toll (it can be shown that $\partial[\text{consumer benefits}]/\partial t$ evaluated at t as given in (18) is always negative). The toll in (18) does not take into account any losses in consumer benefits

Finally, using (11), we find that the toll equals (1-flight share)×damage, as in Brueckner (2003), when we would set airline specific tolls, although this rule has little meaning in the symmetric case. The asymmetric case, with airport specific congestion tolls and market specific subsidies, will be analyzed in the next section.

Variations on the regulator's maximization problem

The tolls in the previous subsection are "first-best" in the sense that total welfare is maximized without any restrictions. In practice, it may be, however, that the airlines play a Stackelberg-type of game, in which the authorities first set a welfare-maximizing congestion toll, to which the airlines then respond. In effect, welfare is them maximized with respect to the toll, after the optimal qs are substituted in the welfare function:

$$\max_{t_h} \varpi_G = \int_0^{2q^*} (\alpha - \beta x)dx - 2q^* vot_p \frac{2q^*}{\lambda} - 2q^* \left[\frac{1}{\lambda_i}\left(c^f + vot_i \frac{2q^*}{\lambda}\right) + c^q \right] \tag{21}$$

The first-order necessary condition for welfare maximization is

$$(\alpha - 2\beta q^*)2\frac{\partial q^*}{\partial t} - 8 vot_p \frac{q^*}{\lambda}\frac{\partial q^*}{\partial t} - 2\frac{\partial q^*}{\partial t}\left[\frac{1}{\lambda}\left(c^f + vot_i \frac{2q^*}{\lambda}\right) + c^q \right] - \frac{4q^*}{\lambda^2} vot_i \frac{\partial q^*}{\partial t} = 0 \tag{22}$$

The interpretation of the first-order condition is as follows. A change in t causes a change in q, and thus also the consumer benefits; this is indicated by the first LHS-term. Furthermore, because the total number of passengers changes, total congestion costs change. This is indicated by the second LHS-term. Airline (operating and congestion) costs also change, as indicated by the third and fourth RHS-term. Solving the first-order condition yields the following toll rule:

$$t = \frac{1}{4}\frac{\left(\alpha\lambda - c^q\lambda - c^f\right)\left(2\eta_h\left[\lambda vot_p + vot_i\right] - \beta\lambda^2\right)}{\beta\lambda^2 + 4\eta_h\left(vot_p\lambda + vot_i\right)} \tag{23}$$

Comparing (23) and (20), we see that the second-best (Stackelberg) toll exceeds the welfare maximizing toll. This stands to reason. When the airlines and the regulator play a Stackelberg-game (rather than the game in which the regulator sets a first-best welfare maximizing toll), airline profits will most likely be higher because airlines maximize their profits. A lower output means lesser congestion damage, so that the congestion part of the toll is lower than the congestion toll in (18). The market power subsidy will be necessarily higher

(in absolute value) compared to the subsidy in (19), but because the congestion effect dominates, the overall toll is lower (in absolute value).

4   NUMERICAL ANALYSIS

In this section, numerical solutions for the network in Figure 1 are presented. These solutions serve two purposes. Firstly, they allow us to check the welfare effects of a pure congestion toll in a market where (symmetric) airlines have market power. Secondly, we can analyze the asymmetric equilibrium, for which the analytical solutions are more difficult to interpret.

The necessary demand characteristics are given in Table 2; airline characteristics in Table 3, and airport characteristics in Table 4. It is not the purpose of this paper to accurately describe a real-life aviation network. The parameters therefore may also not correspond to real life values. In the simulation, we will calculate the price elasticity of demand and compare this estimates from the literature to validate our results.

α	30000
β	4

Table 1. Demand characteristics

λ	200	c^f	100000	c^q	100

Table 2.   Transport   network   operator characteristics

vot_l	50	η_A	0.5
vot_p	5		

Table 3. Node characteristics

Table 4 contains the no-toll equilibrium. The calculated price elasticity in equilibrium of −1.17 roughly corresponds to the value of −1.146 reported by Brons et al. (2002). The latter number is the overall mean of 204 estimates encountered in the literature. The model thus yields an elasticity in equilibrium that corresponds to real life values; we operate on a relevant segment of the demand curve.

		generalized costs				welfare effects ($\times 10^7$)	
	q	fare	congestion	ε_{price}	local welfare	consumer benefits	profits
airline 1	1862	10447	931	1.17	3.45894	3.85275	1.72499
airline 2	1862	10447	931	1.17	3.45894	3.85275	1.72499

Table 4. Equilibrium outputs and welfare; no toll, elasticity in absolute value

Table 5 contains the equilibrium for the (first-best) welfare maximizing toll (given in equation (20)). The toll is negative, and quite large in absolute value (compared to, for

instance, the marginal cost per flight). This indicates that the market power effect in the no-toll equilibrium exceeds the congestion effect. Because the airlines receive substantial subsidies, the optimal outputs and profits are larger than in the no-toll equilibrium. Because the optimal outputs are higher, congestion costs are also higher. In the no-toll equilibrium, the airlines set their optimal outputs too low, and as a result, the congestion costs are too low in the optimum. The welfare maximizing toll fixes this problem.

	q	generalized costs fare	congestion	ε_{price}	local welfare	welfare effects ($\times 10^7$) consumer benefits	profits
airline 1	2390	4904	1195	0.46	3.77069	8.62801	2.90621
airline 2	2390	4904	1195	0.46	3.77069	8.62801	2.90621

Table 5. Equilibrium outputs and welfare; first-best welfare maximizing toll = -833349; elasticity in absolute value

The equilibrium in Table 5 may only be of academic interest, because subsidizing airlines may be politically rather tricky. Brueckner (2003) suggests that the toll in such a case should be set at the level of congestion that is not internalized by the airlines (equation (18)). This equilibrium is given in Table 6.

	q	generalized costs fare	congestion	ε_{price}	local welfare	welfare effects ($\times 10^7$) consumer benefits	profits
airline 1	1800	11097	900	1.28	3.40219	7.56073	1.60563
airline 2	1800	11097	900	1.28	3.40219	7.56073	1.60563

Table 4. Equilibrium outputs and welfare; Brueckner-toll = 97767; elasticity in absolute value

The toll is positive (as expected), and this is also reflected in consumer prices (the airlines pass the toll on to the passengers). Because the fares increase, consumer benefits decrease. From Table 4 and 5 we already concluded that in the no-toll equilibrium, the airlines set their optimal outputs, and thus also the congestion costs, too low. The 'Brueckner-toll" causes the outputs to be even lower. Combined with the decrease in consumer benefits, this leads to a decrease in total welfare. The straightforward conclusion then is that in this market the regulator should set welfare maximizing tolls. If this is not possible, the regulator should do nothing. Pure congestion tolls do more harm than good.

When we take the first-best optimum as a reference case, it could be more for the airlines to act as followers in a Stackelberg-like game with the airports authorities. The airports then set a toll to which the airlines respond; in practice, this means that the optimal outputs from the airline point of view are substituted in the regulator's objective function. The

airlines thus obtain the maximum possible profits, conditional on the toll, while this is not the case in the first-best optimum. Because the airlines receive a subsidy for each passenger they move, they maximize the output up to the point where the "production" costs, including congestion costs, of the marginal passenger exceed the revenues (including subsidy). This is reflected in Table 6. The optimal output exceeds the optimal output in the first-best optimum. In theory, the airlines thus have an incentive to act as followers.

| | | generalized costs | | | | welfare effects ($\times 10^7$) | |
	q	fare	congestion	ε_{price}	local welfare	consumer benefits	profits
airline 1	2661	2063	1330	0.21	3.81113	8.88483	.3.62531
airline 2	2661	2063	1330	0.21	3.81113	8.88483	.3.62531

Table 6. Equilibrium outputs and welfare; second-best welfare maximizing toll = -1260480; elasticity in absolute value

CONCLUSION

Conventional economic wisdom suggests that congestion pricing would be an appropriate response to cope with the growing congestion levels currently experienced at many airports. Several characteristics of aviation markets, however, may make naïve congestion prices equal to the value of marginal travel delays a non-optimal response. This paper has developed a model of airport pricing that captures a number of these features. The model in particular reflects that airlines typically have market power and are engaged in oligopolistic competition at different sub-markets; that part of external travel delays that aircraft impose are internal to an operator and hence should not be accounted for in congestion tolls. We presented an analytical treatment for a simple bi-nodal symmetric network, which through the use of 'hyper-networks' would be readily applicable to dynamic problems (in discrete time) such as peak – off-peak differences, and some numerical exercises for the same symmetric network, which was only designed to illustrate the possible comparative static impacts of tolling, in addition to marginal equilibrium conditions as could be derived for the general model specification.

Some main conclusions are that second-best optimal tolls are typically lower than what would be suggested by congestion costs alone and may even be negative, and that the toll as derived by Brueckner (2002) may not lead to an increase in total welfare.

While Brueckner (2002) has made clear that congestion tolls on airports may be smaller than expected when congestion costs among aircraft are internal for a firm, our

analysis adds to this that a further downward adjustment may be in order due to market power. The presence of market power (which causes prices to exceed marginal costs) may cause the pure congestion toll to be suboptimal, because the resulting decrease in demand is too high (the pure congestion toll does not take into account the decrease in consumer surplus).

The various downward adjustments in welfare maximizing tolls may well cause the optimal values of these to be negative. Insofar as subsidization is considered unacceptable for whichever reason, our results warn that the most efficient among the non-negative tolls may actually be a zero toll; the pure congestion toll may actually decrease welfare compared to the base case.

The model in this paper contains a few simplifying assumptions that may be relaxed in future work. Load factors and aircraft capacity are fixed in this model for simplicity. In a more advanced version of this model, load factors and aircraft capacity can be endogenized. This makes the derivation of the optimality conditions far more complicated, but it should be feasible in a numerical experiment. One can also add a fourth layer to the model, describing the airport's optimization problem. For example, the airport can maximize profits under a cost recovery constraint. The model then deals with interactions between four types of agents. No distinction is made between peak and off-peak traffic in this paper. This distinction is quite common in the literature (see e.g. Brueckner (2002), Daniel (1995)) and could, as discussed, make a straightforward but important extension of the model in this paper. Finally, the results of the numerical exercise in this paper need to be checked against an asymmetric equilibrium.

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Auction Mechanism to Allocate Air Traffic Control Slots

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Abstract

This article deals with an auction mechanism for airspace slots, as a means of solving the European airspace congestion problem. A disequilibrium, between Air Traffic Control (ATC) services supply and ATC services demand, are at the origin of almost one fourth of delays in the air transport industry in Europe. In order to tackle this congestion problem, we suggest modifying both pricing and allocation of ATC services, by setting up an auction mechanism. Objects of the auction will be the right for airlines to cross a part of the airspace, and then to benefit from ATC services over a period corresponding to the necessary time for the crossing. Allocation and payment rules have to be defined according to the objectives of this auction. The auctioneer is the public authority in charge of ATC services, whose aim is to obtain an efficient allocation. Therefore, the social value will be maximized. Another objective is to internalize congestion costs. To that end, we apply the principle of Clarke-Groves mechanism auction: each winner has to pay the externalities imposed on other bidders. The complex context of ATC leads to a specific design for this auction.

1 Introduction

The air transport industry in Europe is faced with the recurring problem of delays. Although delays slightly decreased in 2001, this was essentially due to the current international context. Delay and traffic levels are strongly connected. High rate of flight delays can again become very topical with

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future growth of the air transport industry. Delays are very costly in terms of welfare.

The reason essentially advanced by airlines to explain delays is the insufficient capacity of the Air Traffic Control (ATC). A study estimates the cost of those specific delays, borne by passengers and airlines, between 6.6 and 10.7 billions of euros for 1999. It is very important to tackle this problem.

However, if ATC services are actually responsible for an important part of European delays, airlines are also at the origin of this situation: under-capacity is due to insufficient supply and too much demand.

The aim of this article is to propose a solution to the inadequacy of the supply to cope with the demand, by considering a fixed capacity. Pricing is the mechanism usually used to avoid such disequilibrium. We observe that ATC fees do not satisfied this principle. Indeed, ATC charges are a function of the weight of the aircraft in order to introduce cross subsidies between airspace users, and of the distance flown over in order to reflect the cost of service. The ATC fees provide incentives to operate flights on small aircraft and to supply frequent flights, but frequencies contribute to air congestion. Thus, ATC charges do not work to reduce delays.

Another problem is the organization of ATC services, such that the upper airspace is divided into "sectors" with a team of two or three controllers in charge of one sector. When the demand is greater than the supply for one sector, ATC authorities have to "regulate" the traffic and to allocate slots. The time an aircraft is allowed to enter in a regulated sector is specified in a slot. For each regulated sector, a list of slots is built. Those slots satisfied the capacity per hour announced by the regulated sector. For instance, a four hour long regulation associated with a rate of 30 flights per hour would result in a slot allocation list made up of 120 slots separated from one another by 2 minutes. The principle "first planned, first served", which presumes that flights should arrive over the restricted sector in the same order in which they would have arrived without regulation, is applied throughout the process.

ATC fees and allocation rules do not produce an efficient treatment of congestion. This article proposes a mechanism which combines allocation and pricing. Allocation of slots will be done in an efficient way, via optimal ATC fees.

First, we need to present the specific context of auction for airspace. Then, we will be able to design allocation and payment rules of the mechanism. The public authority is faced with some constraints, as capacity constraints, to determine the optimal allocation. Airlines' payoffs have to be defined according to the objectives. Finally, we will provide an example to understand how the mechanism works and to analyze the results.

2

2 Context of auction for airspace

In order to define an auction mechanism, we need to present objects and objectives for the auction. The wide complexity of the ATC organization, explained by a high level of security, is at the origin of a specific definition of objects. They will be presented in detail. Objectives are more simple: a public authority in charge of ATC services sets up an auction with the aim of reducing delays and promoting a better use of the existing capacity.

2.1 Objects of the auction

An auction for the airspace will be the selling of rights for airlines to cross a part of the airspace, and then to benefit from ATC services over a period corresponding to the necessary time to cross. Those rights will be called "slots", as for the airport slots, but with a different sense of current "ATC slots".

Obviously, there are many objects in this auction. Two elements are at the origin of this multiplicity: space and time.

2.1.1 Components of a slot

The airspace is divided into "sectors". The work of a team of controllers is to ensure security to flights crossing the sector they are in charge of. Most of air links cross many sectors. It means many different goods.

Moreover, a sector is defined by its capacity. This the highest number of flights that can be present in the same sector at the same moment. A given sector can be crossed by several flights during a given period. It means many identical goods. Those goods are perfect complements because airlines cannot run a risk of missing a sector to operate a link. It is absolutely necessary to allow package bids from individual sectors.

Another important dimension to constitute a slot is the time. Each package must also include periods at which sectors will be crossed.

For security reasons, air traffic flow must be spread over the day and cannot be concentrated over a short period. Thus, a sector capacity cannot be defined by day. It has to be fixed for a short period. We divided a day into 34 periods of half an hour: 6:00-6:30, 6:30-7:00, etc. The auction is organized for flights in airspace between 6:00 in the morning and 11:00 in the evening. The set of sub-periods of one day is:

$$T = \{t_1, \ldots, t_{34}\}$$

The division into airspace sectors already exists. The set of those sector is: $X = \{1, \ldots, x\}$. Each sector is characterized by a time capacity. Due to the activation of some military areas, where civil flights are not allowed to cross, this capacity varies over the periods. We consider $k_{s;t}$ as the capacity of the sector s during the period t.

2.1.2 Complementary objects

A slot is not necessary only for one flight or for only one air link. For strategic reasons, airlines can bid for a slot used for several air links. Sectors for a same flight are not the only perfect complements. Flight periods of several air links need to be consistent with each other, due to aircraft turnover. The existence of a hub explains also the strong complementarity between sectors. Then, slots can be for an air link, or for several air links of an aircraft, or for several air links of a group of passengers.

An airline bid specifies which sectors, at which periods, are necessary to form a package. Generally, flights will be operated over several periods. A slot z will be pairs of "sectors-period": $z = \{[(y_a, t_a)]_{a=1,\ldots,A}\}$, with y_a a package of sectors, t_a the time period needed for the package y_a and A the number of necessary periods to operate the flight.

Airlines can ask for many slots. So, this auction is for multiple packages.

2.2 Objectives of the auction

Many objectives justify an auction mechanism for airspace.

2.2.1 Internalize congestion costs

ATC services are not a public good. On one hand, fees paid by users involve possibility of exclusion. On the other hand, periodic situation of congestion involve rivalry. With the limited capacity of ATC services, airlines impose externalities on others.

One aim of this auction is to lead airlines to take into account the consequences of theirs flight choices. We need to know the value of each slot for airlines. If the demand of airlines for a slot is not satisfied, they bear an opportunity cost. This cost is equal to the profit that airlines would obtain if the demand has been satisfied, minus fees for the slot. The airlines ability to pay for a slot is the amount of this opportunity cost.

If this cost is revealed by the auction, it will be possible to charge winners the externality imposed on others.

2.2.2 Reach an efficient allocation of slots

Although ATC services are not a public good, a public authority is in charge of them. In the collective interest, this authority would prefer to reach the highest social surplus than the highest revenue. We look for an efficient mechanism.

The social surplus is equal to the sum of the airlines' net surplus, passengers' net surplus and ATC revenues. With "yield management" strategies, airlines capture passengers' surplus. ATC costs for airlines and ATC revenues cancel each other out. Thus, after simplification, social surplus is equal to the sum of bids of winners, because we saw, that airlines' net profit plus ATC cost are equal to their bids.

One objective is the maximization of this welfare.

2.2.3 Spread the traffic over time and space

We decided to study an auction mechanism for airspace slots in order to solve the present problem of congestion. The goal of this system is also to spread the traffic over time and space and not to cancel flights initially forecasted at a peak period.

The interest of an auction mechanism in this context is to incite airlines to modify either flight route, or flight hour, or both, when the capacity is insufficient, by means of prices. The optimal period to flight and the optimal sectors to cross will be determined according to ability to pay.

2.2.4 Balance the ATC services budget

France, as most in countries, decided to charge direct users of airspace. An auction mechanism is at the origin of transfers from bidders to the auctioneer. However, it is not sure that the budget of the civil aviation administration will be balanced.

For this reason, we suggest to separate the fees in two parts. One will be connected to the ATC service costs and the other will be linked to the congestion costs. This second part will be determined by the auction results.

3 Auction design

Due to multiple packages, the auction design specifies not only allocation and payment rules but also what bids look like. Airlines will have to announce which slots they want and how much they are able to pay for them.

An optimization of the total value of the bids, under constraints, will give the allocation and the objectives will induce a special payment rule. Indeed, externalities and services managed by a public authority are in favor of a mechanism such that winners pay the cost imposed on others. So, the auction mechanism for airspace slots will be an adaptation of a Clarke-Groves mechanism.

3.1 Bids of the auction

There is a lot of possible "sector-period" combination. So, we propose to leave airlines to define themselves their slots.

Bids of the auction will have two components. First, airlines will describe precisely the slots which are relevant to them. Second, they will announce their values for those slots.

3.1.1 Relevant slots

The auctioneer cannot propose an exhaustive list of all possible slots. Airline i will describe the M^i slots it wants. The first part of her announcement will be the list $Z^i = \{z_m^i\}_{m=1,\dots,M^i}$.

Considering the third objective, it is not possible that at the end of the auction, some forecasted flights at peak period are canceled and all capacity is not used at off-peak period. The auctioneer can allow airlines to modify a slot if their demand is not satisfied. We suggest to implement an auction with only one turn and to leave airlines asking for several slots for the same flight. At their "favorite" slot, they will add others slots in case of insufficient capacity to obtain the first one. Those alternatives will be different from the "first choice", either by the time period, earlier or later, or by sectors, a longer but less congestioned route, or by both.

Thus, for an air link, airlines ask for several slots. $z_m^i = \{z_m^{i;r}\}_{r=1,\dots,R_m^i}$ is a vector including all the slots described by airline i to operate the air link m.

For a given air link m, the smaller is r, the more the airline prefers this slot. It means that slots with $r = 1$ are "favorite" slots.

With the previous notation, the slot r asked by the airline i for its air link m is: $z_m^{i;r} = \{[(y_{m;a}^{i;r}, t_{m;a}^{i;r})]_{a=1,\dots,A_m^{i;r}}\}$.

3.1.2 Slots values

In addition to describing slots for their air links, airlines must also announce how much they are able to pay for them. For each airline i, bids are contained

in the list of price: $B^i = \{b^i_m\}_{m=1,\ldots,M^i}$.

As for the slots, b^i_m is a vector including bids for all the slots asked for a given air link. Bids are classified in order of preference: $b^i_m = \{b^{i;r}_m\}_{r=1,\ldots,R^i_m}$, such that $b^{i;r}_m$ is greater than $b^{i;r+1}_m$ for all r in the set $[1, R^i_m - 1]$.

According to information they have, airlines announce their bids. Consider that θ^i in Θ^i, is the exogenous private information of airline i. The set of all bidders' private information is $\Theta = \Theta^1 \times \ldots \times \Theta^n$ and the vector of all bidders' signals is $\theta = (\theta^1, \ldots, \theta^n)$, with θ in Θ.

For each airline i, abilities to pay is defined as following:

$$v^{i;r}_m : \Theta^i \longrightarrow \mathbb{R}^+, \forall r = 1, \ldots, R^i_m, \forall m = 1, \ldots, M^i,$$

where $v^{i;r}_m(\theta^i)$ is the willingness to pay of the airline i with the signal θ^i for her slot r, for its air link m. For notation: $V^{i;r}_m = \{v^{i;r}_m(\theta^i)/\theta^i \in \Theta^i\}$.

Then:

$$v^i : \Theta^i \longrightarrow \mathbb{R}^{\left(\sum_{m=1}^{M^i} R^i_m\right)+}$$
$$\text{such that} \quad v^i(\theta^i) = \{v^{i;r}_m(\theta^i)/r = 1, \ldots, R^i_m, m = 1, \ldots, M^i\}$$

Airlines' bids are based on their own willingness to pay for goods:

$$b^{i;r}_m : \Theta^i \longrightarrow \mathbb{R}^+$$
$$\hat{b}^{i;r}_m[v^{i;r}_m(\theta^i)] = b^{i;r}_m(\theta^i)$$

The complete airline i's bid is $D^i = (Z^i; B^i)$, with:

$$\begin{cases} Z^i &= \{\{[(y^{i;r}_{m;a}, t^{i;r}_{m;a})]_{a=1,\ldots,A^{i;r}_m}\}_{r=1,\ldots,R^i_m}\}_{m=1,\ldots,M^i} \\ B^i &= \{\{b^{i;r}_m\}_{r=1,\ldots,R^i_m}\}_{m=1,\ldots,M^i}. \end{cases}$$

The component $z^{i;r}_m = \{[(y^{i;r}_{m;a}, t^{i;r}_{m;a})]_{a=1,\ldots,A^{i;r}_m}\}$ of Z^i is associated with the component $b^{i;r}_m$ of B^i.

3.2 Results of the auction

With the objectives we fixed to design an auction mechanism, a Clarke-Groves mechanism will be suitable for airspace slots auction. Such a system can be used when either a single public good is sold or many private goods are sold to many people. In a Clarke-Groves mechanism, payoff of an agent is connected to its bid only through the consequences its bid has on the final allocation or decision. The price he pays is independent of its bid. Let's see how this price will be computed for airspace slots, after the announcement of the final allocation.

3.2.1 Allocation rule

Once airlines passed on their bids, made of slots and willingness to pay, the auctioneer computes the maximum social surplus. Then, the auctioneer announces to airlines which slots they obtained. The allocation list of airline i is given by $H^i = \{h^i_1, \ldots, h^i_{M^i}\}$, such that $h^i_m = \{h^{i;r}_m\}_{r=1,\ldots,R^i_m}$ is equal to one if it won the slot and to zero otherwise:

$$h^{i;r}_m \in \{0,1\}, \ \forall i, \forall m, \forall r \tag{1}$$

Moreover, h^i_m cannot contain more than one element equal to one, because all bids are for the same air link:

$$\sum_{r=1}^{R^i_m} h^{i;r}_m \in \{0,1\}, \ \forall i, \forall m \tag{2}$$

Finally, capacity constraint must be satisfied by the final allocation:

$$\sum_{i=1}^{n} \sum_{m=1}^{M^i} \sum_{r=1}^{R^i_m} \sum_{a=1}^{A^{i;r}_m} \left(h^{i;r}_m \times \mathbf{1}_{s \in y^{i;r}_{m;a}} \times \mathbf{1}_{t=t^{i;r}_{m;a}} \right) \leq k_{s;t}, \ \forall s \in X, \forall t \in T \tag{3}$$

We obtain the allocation of slots among airspace users by maximizing the sum of the ability to pay for slots, under constraints (1), (2) and (3). The allocation is given by $H = (H^1, \ldots, H^i, \ldots, H^n)$, with $H^i = \{\{h^{i;r}_m\}_{r=1,\ldots,R^i_m}\}_{m=1,\ldots,M^i}$, solution of the auctioneer program:

$$\max_{\left\{ \{\{h^{i;r}_m\}_{r \in [1, R^i_m]}\}_{m \in [1, M^i]} \right\}_{i \in N}} \sum_{i=1}^{n} \sum_{m=1}^{M^i} \sum_{r=1}^{R^i_m} b^{i;r}_m \times h^{i;r}_m \tag{4}$$

under the constraints:

$$\begin{cases} \sum_{i=1}^{n} \sum_{m=1}^{M^i} \sum_{r=1}^{R^i_m} \sum_{a=1}^{A^{i;r}_m} \left(h^{i;r}_m \times \mathbf{1}_{s \in y^{i;r}_{m;a}} \times \mathbf{1}_{t=t^{i;r}_{m;a}} \right) \leq k_{s;t}, \forall s \in X, \forall t \in T \\ h^{i;r}_m \in \{0,1\}, \forall i, \forall m, \forall r \\ \sum_{r=1}^{R^i_m} h^{i;r}_m \in \{0,1\}, \forall i, \forall m \end{cases}$$

3.2.2 Payment rule

The auctioneer informs winners of the slots cost. To compute the price paid by agent i for slot m, he needs to know what would be the allocation $L(i;m)$, if agent i did not bid for slot m. It is a vector such that:

$$
\begin{aligned}
L(i;m) &= (L^1(i;m),\dots,L^i(i,m),\dots,L^n(i;m)) \\
\text{with} \quad L^j(i;m) &= \{l_1^j(i;m),\dots,l_{M^j}^j(i;m)\} \\
\text{and} \quad l_m^i(i;m) &= \{l_m^{i;r}(i;m)\}_{r=1,\dots,R_m^i} = \{0\}_{r=1,\dots,R_m^i}
\end{aligned}
$$

We obtain this allocation by solving:

$$
\max_{\left\{\left\{\{l_{m'}^{j;r}(i;m)\}_{r\in[1,R_{m'}^j]}\right\}_{m'\in[1,M^j]}\right\}_{j\in N}} \sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R_{m'}^j} b_{m'}^{j;r} \times l_{m'}^{j;r}(i;m) \tag{5}
$$

under constraints:

$$
\left\{
\begin{aligned}
& \sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R_{m'}^j}\sum_{a=1}^{A_{m'}^{i;r}} \left(l_{m'}^{i;r}(i;m) \times \mathbf{1}_{s\in \mathcal{Y}_{m';a}^{j;r}} \times \mathbf{1}_{t=t_{m';a}^{j;r}} \right) \le k_{s;t}, \forall s\in X, \forall t\in T \\
& l_{m'}^{j;r}(i;m) \in \{0,1\}, \forall j\ne i, \forall m', \forall r \\
& l_{m'}^{i;r}(i;m) \in \{0,1\}, \forall m'\ne m, \forall r \\
& l_m^{i;r}(i;m) = 0, \forall r \\
& \sum_{r=1}^{R_{m'}^j} l_{m'}^{j;r}(i;m) \in \{0,1\}, \forall i, \forall m'
\end{aligned}
\right.
$$

Then, the agent i must pay for the slot m:

$$
\begin{aligned}
p_m^i &= \sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R_{m'}^j} b_{m'}^{j;r} \times l_{m'}^{j;r}(i;m) \\
&\quad - \left(\sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R_{m'}^j} b_{m'}^{j;r} \times h_{m'}^{j;r} - \sum_{r=1}^{R_m^i} b_m^{i;r} \times h_m^{i;r} \right) \\
&= \sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R_{m'}^j} b_{m'}^{j;r} \times l_{m'}^{j;r}(i;m) \\
&\quad - \left(\sum_{\substack{j=1 \\ j\ne i}}^{n}\sum_{m'=1}^{M^j}\sum_{r'=1}^{R_{m'}^j} b_{m'}^{j;r'} \times h_{m'}^{j;r'} + \sum_{\substack{m'=1 \\ m'\ne m}}^{M^i}\sum_{r'=1}^{R_{m'}^i} b_{m'}^{i;r'} \times h_{m'}^{i;r'} \right)
\end{aligned}
\tag{6}
$$

This price is the difference between the total bids of all airlines, except i, when airline i does not bid for the air link m and when it bids for this air link. Then p_m^i reflects the amount of which airline i deprives other bidders with its demand for m.

The price can also be written:

$$
p_m^i = \sum_{r=1}^{R_m^i} b_m^{i;r} \times h_m^{i;r} - \sum_{j=1}^{n} \sum_{m'=1}^{M^j} \sum_{r=1}^{R_{m'}^j} \left(b_{m'}^{j;r} \times h_{m'}^{j;r} - b_{m'}^{j;r} \times l_{m'}^{j;r}(i;m) \right)
$$

In this way, another interpretation is possible. Airline i pays its bid for the slot it won, for its air link m, and it benefits from a discount equal to the amount it increases the final allocation value with its demand.

Prices correspond to externalities that airlines imposed on other bidders.

Proposition 1 *This mechanism is a direct revealing and efficient mechanism.*

Proof is given in annex A.

4 Example

In order to understand what the process is of the auction, we give a simple example with less parameters than in an actual situation.

4.1 Data of the simulation

We consider:

- 4 airlines: $i = 1, 2, 3, 4$;

- 6 ATC sectors: $s = s_1, s_2, s_3, s_4, s_5, s_6$, laid out as on the figure (1):

- 3 time periods: $t = t_1, t_2, t_3$;

- a capacity for each sector at each time period equal to 2 aircraft: $k_{s;t} = 2$, $\forall s, t$.

Each airline describes the slots it wants and the substitute slots in case it would not obtain its favorite slot. The slot r of the airline i for its air link m is $z_m^{i;r}$ and is associated with the ability to pay $v_m^{i;r}$. Given that the mechanism is efficient and direct revealing, we know that the airlines' bids
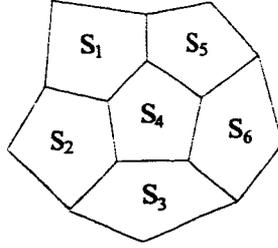
Figure 1: Layout of the 6 sectors.

are equal to their ability to pay. We suppose that the airlines' bids are the
following:

Airline 1: ⋆ 1st link   - 1st choice: $\begin{cases} z_1^{1;1} &= \{[(s_1, s_2, s_4), t_1], [(s_3, s_6), t_2]\} \\ v_1^{1;1} &= 70 \end{cases}$

    - 2nd choice: $\begin{cases} z_1^{1;2} &= \{[(s_1, s_2), t_1], [(s_3, s_4, s_6), t_2]\} \\ v_1^{1;2} &= 62 \end{cases}$

    - 3rd choice: $\begin{cases} z_1^{1;3} &= \{[(s_1, s_2, s_4), t_2], [(s_3, s_6), t_3]\} \\ v_1^{1;3} &= 53 \end{cases}$

⋆ 2nd link: -1st choice: $\begin{cases} z_2^{1;1} &= \{[s_2, t_1], [s_1, t_2]\} \\ v_2^{1;1} &= 16 \end{cases}$

    - 2nd choice: $\begin{cases} z_2^{1;2} &= \{(s_1, s_2), t_2\} \\ v_2^{1;2} &= 13 \end{cases}$

    - 3rd choice: $\begin{cases} z_2^{1;3} &= \{[s_2, t_2], [s_1, t_3]\} \\ v_2^{1;3} &= 10 \end{cases}$

Airline 2: ⋆ 1st link: - 1st choice: $\begin{cases} z_1^{2;1} &= \{[(s_1, s_4), t_1], [s_6, t_2]\} \\ v_1^{2;1} &= 32 \end{cases}$

    - 2nd choice: $\begin{cases} z_1^{2;2} &= \{[(s_1, s_5), t_1], [s_6, t_2]\} \\ v_1^{2;2} &= 27 \end{cases}$

    - 3rd choice: $\begin{cases} z_1^{2;3} &= \{[s_1, t_1], [(s_4, s_6), t_2]\} \\ v_1^{2;3} &= 25 \end{cases}$

    - 4th choice: $\begin{cases} z_1^{2;4} &= \{[(s_1, s_5), t_2], [s_6, t_3]\} \\ v_1^{2;4} &= 21 \end{cases}$

$\star$ 2$^{\text{nd}}$ link: - 1$^{\text{st}}$ choice: $\begin{cases} z_2^{2;1} &= \{[(s_3, s_6), t_1], [s_2, t_2]\} \\ v_2^{2;1} &= 26 \end{cases}$

- 2$^{\text{nd}}$ choice: $\begin{cases} z_2^{2;2} &= \{[s_3, t_1], [(s_2, s_6), t_2]\} \\ v_2^{2;2} &= 24 \end{cases}$

- 3$^{\text{rd}}$ choice: $\begin{cases} z_2^{2;3} &= \{[(s_3, s_6), t_2], [s_2, t_3]\} \\ v_2^{2;3} &= 21 \end{cases}$

- 4$^{\text{th}}$ choice: $\begin{cases} z_2^{2;4} &= \{[s_3, t_2], [(s_2, s_6), t_3]\} \\ v_2^{2;4} &= 17 \end{cases}$

$\star$ 3$^{\text{rd}}$ link: - 1$^{\text{st}}$ choice: $\begin{cases} z_3^{2;1} &= \{(s_3, s_4), t_1\} \\ v_3^{2;1} &= 22 \end{cases}$

- 2$^{\text{nd}}$ choice: $\begin{cases} z_3^{2;2} &= \{[s_3, t_1], [s_4, t_2]\} \\ v_3^{2;2} &= 19 \end{cases}$

- 3$^{\text{rd}}$ choice: $\begin{cases} z_3^{2;3} &= \{(s_3, s_4), t_2\} \\ v_3^{2;3} &= 13 \end{cases}$

Airline 3: $\star$ 1$^{\text{st}}$ link: - 1$^{\text{st}}$ choice: $\begin{cases} z_1^{3;1} &= \{[(s_4, s_5), t_1], [(s_4, s_5), t_2]\} \\ v_1^{3;1} &= 52 \end{cases}$

- 2$^{\text{nd}}$ choice: $\begin{cases} z_1^{3;2} &= \{[(s_4, s_5), t_2], [(s_4, s_5), t_3]\} \\ v_1^{3;2} &= 34 \end{cases}$

- 3$^{\text{rd}}$ choice: $\begin{cases} z_1^{3;3} &= \{(s_4, s_5), t_3\} \\ v_1^{3;3} &= 20 \end{cases}$

$\star$ 2$^{\text{nd}}$ link: - 1$^{\text{st}}$ choice: $\begin{cases} z_2^{3;1} &= \{[s_2, t_1], [s_1, t_2]\} \\ v_2^{3;1} &= 21 \end{cases}$

- 2$^{\text{nd}}$ choice: $\begin{cases} z_2^{3;2} &= \{(s_1, s_2), t_2\} \\ v_2^{3;2} &= 17 \end{cases}$

- 3$^{\text{rd}}$ choice: $\begin{cases} z_2^{3;3} &= \{[s_2, t_2], [s_1, t_3]\} \\ v_2^{3;3} &= 13 \end{cases}$

Airline 4: $\star$ 1$^{\text{st}}$ link: - 1$^{\text{st}}$ choice: $\begin{cases} z_1^{4;1} &= \{[(s_3, s_6), t_1], [s_5, t_2]\} \\ v_1^{4;1} &= 20 \end{cases}$

- 2$^{\text{nd}}$ choice: $\begin{cases} z_1^{4;2} &= \{[s_3, t_2], [(s_5, s_6), t_2]\} \\ v_1^{4;2} &= 17 \end{cases}$

- 3$^{\text{rd}}$ choice: $\begin{cases} z_1^{4;3} &= \{[(s_3, s_6), t_2], [s_5, t_3]\} \\ v_1^{4;3} &= 14 \end{cases}$

$\star$ 2$^{\text{nd}}$ link: - 1$^{\text{st}}$ choice: $\begin{cases} z_2^{4;1} &= \{(s_1, s_2), t_2\} \\ v_2^{4;1} &= 18 \end{cases}$

- 2$^{\text{nd}}$ choice: $\begin{cases} z_2^{4;2} &= \{[s_2, t_2], [s_1, t_3]\} \\ v_2^{4;2} &= 15 \end{cases}$

- 3$^{\text{rd}}$ choice: $\begin{cases} z_2^{4;3} &= \{(s_1, s_2), t_3\} \\ v_2^{4;3} &= 12 \end{cases}$

Interpretation of those demands is appended to (see annex B).

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4.2 Results

From those bids and capacity constraints, we can solve the program (4). The optimal allocation is:

$$H = \{[(1,0,0),(0,1,0)],[(0,1,0,0),(0,0,0,1),(0,1,0)],$$
$$[(1,0,0),(1,0,0)],[(1,0,0),(0,1,0)]\}$$

Results are resumed in the following tabular:

	1st link	2nd link	3rd link
Airline 1	1st choice	2nd choice	-
Airline 2	2nd choice	4th choice	2nd choice
Airline 3	1st choice	1st choice	-
Airline 4	1st choice	2nd choice	-

The social value, computed by adding the abilities to pay for allocated slots, is equal to 254 monetary units.

Then, we have to compute the price of each slot. We solve the program (5) several times, by removing alternatively an air link of an airline. The tabular 1 gives all the new allocations. If the airline i does not receive any slot for its air link m, the allocation is $L(i,m)$. It means that components of the slot z_m^i are available to make other slots. Then, new allocations are possible.

For example, with the components of the slot $z_1^{3;1}$ available, it becomes optimal to allocate to the second airline its first choice instead of its second choice for its first air link, with all other slots still allocated in the same way. The airline 2 can benefit from the sector s_4 at the period t_1 to operate its flight avoiding to make a detour through the sector s_5. With the allocation $L(3,1)$, the sum of the willingness to pay is equal to 277.

We can compute the price of each slot. It is the willingness to pay for it minus the difference between the sum of the willingness to pay of allocated slots, 254 monetary units, and the one of slot that would be allocated if the airline did not bid for this air link. Prices of the nine slots are given by the set of equations (7).

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| Air Link | Airline 1 | | | | | | Airline 2 | | | | | | | | | | | Airline 3 | | | | | | Airline 4 | | | | | | Value |
| | 1 | | | 2 | | | 1 | | | | 2 | | | | 3 | | | 1 | | | 2 | | | 1 | | | 2 | | | |
Choice	1	2	3	1	2	3	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	total
L(1,1)	[(0	0	0)	(1	0	0)]	[(1	0	0	0)	(0	0	1	0)	(0	1	0)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(0	1	0)]	196
L(1,2)	[(1	0	0)	(0	0	0)]	[(0	1	0	0)	(1	0	0	0)	(0	0	1)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(1	0	0)]	247
L(2,1)	[(1	0	0)	(0	1	0)]	[(0	0	0	0)	(0	0	1	0)	(0	1	0)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(0	1	0)]	231
L(2,2)	[(1	0	0)	(0	1	0)]	[(0	1	0	0)	(0	0	0	0)	(0	1	0)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(0	1	0)]	237
L(2,3)	[(1	0	0)	(0	1	0)]	[(0	1	0	0)	(1	0	0	0)	(0	0	0)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(0	0	1)]	241
L(3,1)	[(1	0	0)	(0	1	0)]	[(1	0	0	0)	(0	0	0	1)	(0	1	0)]	[(0	0	0)	(1	0	0)]	[(1	0	0)	(0	1	0)]	207
L(3,2)	[(1	0	0)	(1	0	0)]	[(0	1	0	0)	(1	0	0	0)	(0	0	1)]	[(1	0	0)	(0	0	0)]	[(1	0	0)	(1	0	0)]	242
L(4,1)	[(1	0	0)	(0	1	0)]	[(0	1	0	0)	(1	0	0	0)	(0	1	0)]	[(1	0	0)	(1	0	0)]	[(0	0	0)	(0	0	1)]	240
L(4,2)	[(1	0	0)	(0	1	0)]	[(0	1	0	0)	(1	0	0	0)	(0	0	1)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(0	0	0)]	242
H	[(1	0	0)	(0	1	0)]	[(0	1	0	0)	(0	0	0	1)	(0	1	0)]	[(1	0	0)	(1	0	0)]	[(1	0	0)	(0	1	0)]	254

Table 1: Allocations $L(i, m)$ and H.

$$\begin{cases} p_1^1 & = & 70 - (254 - 196) & = & 12 \\ p_2^1 & = & 13 - (254 - 247) & = & 6 \\ p_1^2 & = & 27 - (254 - 231) & = & 4 \\ p_2^2 & = & 17 - (254 - 237) & = & 0 \\ p_3^2 & = & 19 - (254 - 241) & = & 6 \\ p_1^3 & = & 52 - (254 - 207) & = & 5 \\ p_2^3 & = & 21 - (254 - 242) & = & 9 \\ p_1^4 & = & 20 - (254 - 240) & = & 6 \\ p_2^4 & = & 15 - (254 - 242) & = & 3 \end{cases} \tag{7}$$

Let us understand how those prices are defined. If airline 3 would not win a slot for its first air link, the only change in the optimal allocation will be in favor of airline 2 for its first air link. Instead of winning its second choice, with a value equal to 27 monetary units, it would obtain its first choice, with a value equal to 32 monetary units. Since there would be no bid from airline 3 for its first air link, the increase in the total value would be of 5 monetary units. Then, the price of this slot is: $p_1^3 = 5$.

4.3 Analysis of the results

Some comments can be done on payoffs and on the competition consequences on allocations.

4.3.1 Payoffs

We note that the price of the slot z_2^2 is zero. It means that airline 2 does not deprive any bidders with its slot. Since it would not bid for this slot, any of its components would be allocated to another airline: $L(2,2) = H$. Airline 2 imposes no externality with its slot for its second air link.

With other slots, airlines deprive at least one bidder of getting a better choice. The price they have to pay is different from zero. Nevertheless, sometimes airlines impose externality on themselves. The price paid by an airline is computed for each slot. The authority can define the payoff differently. For example, the price can be computed for the whole set of slots won by airlines. Then, the new allocation we look for is the one when an airline is completely out of the auction. In this way, results would be different from previous ones. To observe the difference, we need to compare the two methods.

The price for the pool of slots obtained by airline 1 is computed by looking for the allocation $L(1)$ of the auction with no demand from airline 1. This is the following allocation with a total value equal to 183:

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$$L(1) \quad = \quad \{[(0,0,0),(0,0,0)],[(1,0,0,0),(0,0,1,0),(0,1,0)],$$
$$[(1,0,0),(1,0,0)],[(1,0,0),(1,0,0)]\}$$

The total value of slots won by airline 1 is 83 ($v_1^{1;1} + v_2^{1;2} = 70 + 13$). The global price is then:

$$p^1 = 83 - (254 - 183) = 12$$

$$p^1 = 12 \neq p_1^1 + p_2^1 = 18$$

This price is less than the sum of the prices for the two slots computed separately. It means that airline 1 imposes externalities not only on others airlines but also on herself, and this latter externality is equal to 6. Indeed, we observe from the allocation $L(1,1)$, with the available slot $z_1^{1;1}$, airline 1 gets a better slot for its second air link.

Another example is for airline 2. If it did not bid in this auction, the allocation would be:

$$L(2) \quad = \quad \{[(1,0,0),(0,1,0)],[(0,0,0,0),(0,0,0,0),(0,0,0)],$$
$$[(1,0,0),(1,0,0)],[(1,0,0),(0,1,0)]\}$$

For airlines 1,3 and 4, the allocation is the same as H. Airline 2 imposes no externality on others bidders. We can guess that the price p^2 is equal to zero. Indeed, the total value of $L(2)$ is 191 and the sum of slots' values of airline 2 is $v_1^{2;2} + v_2^{2;4} + v_3^{2;2} = 63$. Then the price is:

$$p^2 = 63 - (254 - 191) = 0$$

For the other airlines, the global price for slots is equal to the sum of individual price.

4.3.2 Competition

In our example, we observe that airlines are in competition for some air links. The same slot is relevant for airlines 1 and 3. Obviously, due to under-capacity, the airline with the highest value gets the better possible choice.

It is different when the competition is only for a part of the slot. For example, for a slot made of three sectors, airlines 2 and 4 have respectively for their air link 2 and 1, two common sectors. Airline 4 with a value equal to 20 gets the slot, although the value of airline 2 was 26. The slot is in this case, not necessary for the airline with the highest value. This result is due to the other components of the slot. More than sector s_3 and s_6 at

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period t_1, airline 4 needs sector s_5 at period t_2. But there is few demand for this sector. Allocating the slot to airline 4 and the sector s_2 at period t_2 to another airline than airline 2, leads to a greater total value of the objective than otherwise.

5 Concluding remarks

An auction mechanism seems well-suited to the ATC situation. A scarce resource, the airspace, can be efficiently allocated because willingnesses to pay of airlines are revealed. An example shows us consequences of such a mechanism on payoffs and on competition. A price computed by slot and not by airline leads airlines to internalize congestion costs imposed on themselves. From a competition point of view, it is not necessary that the airline with the highest value gets the slots. It can be a solution for airlines to reroute their air link from congestioned areas, keeping a large part of sectors in common with their competitors and to bid a lesser value. Such an airline may win the slot and its competitors not.

To do a computer simulation, we need to have a lot of data about airlines. For the moment, we only know their favorite slots. But we need their alternative slots and their willingness to pay.

Nevertheless, this chosen mechanism leads to reach objectives of this auction. It is a direct revealing and efficient mechanism. The payment rule, as for a Clarke-Groves auction, is at the origin of the incentive effects. A dominant strategy for airlines is to bid their actual ability to pay. But such a mechanism is complex due to multiple packages and alternatives slots.

This auction will be repeated and in each European country a major airline is at the origin of a majority of flights. Collusion problems may also appear.

Moreover, with a Clarke-Groves mechanism we supposed that airlines' values was independent. But those values may be in fact interdependent. The airline's would be a function, not only of her own signal, but also of other airlines' signals and to "collective judgments". A personal characteristic, useful only for itself would be the cost to operate an air link. An airline's ability to pay is connected to this cost. The competition in prices, flights times, frequencies and on board services would be at the origin of interdependency between airlines. For example, if two airlines bid for the same air link, the announcement of one of them would be linked to the effect of its own airline on the network of the other.

In such a case, airlines are no more able to bid their willingness to pay, because it depends on the others. Moreover, the payment rule is no more

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suitable because we can not know what would be the allocation if an airline did not bid.

Dasgupta and Maskin (2000) show that an efficient, but constraint equilibrium exists. From a practical point of view, the mechanism would be more and more complex. Now, research on ATC auction have to take into account this interdependency of values and to remove problems of collusion.

A   Proof of Proposition 1

Let us show that it is a dominant strategy for airline i to bid truthfully for each relevant slot, whatever are bids for other airlines $b_m^{j;r}$. We need to compare net surplus of airline i between the case it bids truthfully for slots of its air link m and the case it lies. Note that the net surplus is equal to the difference between the actual value of the agent and the amount it has to pay.

- $\hat{H}$ is the final allocation when airline i bids truthfully for the R_m^i slots for whom she announced $v_m^{i;r}$, whatever are bids for other airlines:

$$\hat{H} = \underset{\{h_m^{i;r}\}_{r;m;i}}{\arg\max} \sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_{m'=1}^{M^j} \sum_{r'=1}^{R_{m'}^j} b_{m'}^{j;r'} \times h_{m'}^{j;r'} + \sum_{\substack{m'=1 \\ m' \neq m}}^{M^i} \sum_{r'=1}^{R_{m'}^i} b_{m'}^{i;r'} \times h_{m'}^{i;r'} + \sum_{r=1}^{R_m^i} v_m^{i;r} \times h_m^{i;r} \quad (8)$$

under constraints:

$$\begin{cases} \sum_{i=1}^{n} \sum_{m=1}^{M^i} \sum_{r=1}^{R_m^i} \sum_{a=1}^{A_m^{i;r}} \left(h_m^{i;r} \times \mathbf{1}_{s \in y_{m;a}^{i;r}} \times \mathbf{1}_{t=t_{m;a}^{i;r}} \right) \leq k_{s;t}, \quad \forall s, \forall t, \\ h_m^{i;r} \in \{0,1\}, \quad \forall i, \forall m, \forall r, \\ \sum_{r=1}^{R_m^i} h_m^{i;r} \in \{0,1\}, \quad \forall i, \forall m. \end{cases}$$

$\hat{L}(i;m)$ is the allocation when i gets not slot for its air link m:

$$\hat{L}(i;m) = \underset{\left\{\left\{\{l_{m'}^{j;r}(i;m)\}_{r \in [1,R_{m'}^i]}\right\}_{m' \in [1,M^j]}\right\}_{j \in N}}{\arg\max} \sum_{j=1}^{n} \sum_{m'=1}^{M^j} \sum_{r=1}^{R_{m'}^j} b_{m'}^{j;r} \times l_{m'}^{j;r}(i;m) \quad (9)$$

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under constraints:

$$
\begin{cases}
\displaystyle\sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R^j_{m'}}\sum_{a=1}^{A^{i;r}_{m'}}\left(l^{i;r}_{m'}(i;m)\times\mathbf{1}_{s\in\mathcal{Y}^{j;r}_{m';a}}\times\mathbf{1}_{t=t^{j;r}_{m';a}}\right)\le k_{s;t},\ \ \forall s,\forall t, \\[12pt]
l^{j;r}_{m'}(i;m)\in\{0,1\},\ \ \forall j\ne i,\forall m',\forall r, \\[6pt]
l^{i;r}_{m'}(i;m)\in\{0,1\},\ \ \forall m'\ne m,\forall r, \\[6pt]
l^{i;r}_{m}(i;m)=0,\ \ \forall r, \\[6pt]
\displaystyle\sum_{r=1}^{R^j_{m'}}l^{j;r}_{m'}(i;m)\in\{0,1\},\ \ \forall i,\forall m'
\end{cases}
$$

If bidder i bids truthfully, when its net surplus is:

$$
\begin{aligned}
S\left(\hat{H}\right) &= \sum_{r=1}^{R^i_m}v^{i;r}_m\times\hat{h}^{i;r}_m-\left(\sum_{j=1}^{n}\sum_{m'=1}^{M^j}\sum_{r=1}^{R^j_{m'}}b^{j;r}_{m'}\times\hat{l}^{j;r}_{m'}(i;m)\right. \\
&\quad\left.-\left(\sum_{\substack{j=1\\j\ne i}}^{n}\sum_{m'=1}^{M^j}\sum_{r'=1}^{R^j_{m'}}b^{j;r'}_{m'}\times\hat{h}^{j;r'}_{m'}+\sum_{\substack{m'=1\\m'\ne m}}^{M^i}\sum_{r'=1}^{R^i_{m'}}b^{i;r'}_{m'}\times\hat{h}^{i;r'}_{m'}\right)\right)
\end{aligned} \tag{10}
$$

• Now, let us see the case of a liar airline i for slots of its air link m. $\bar{H}$ is the final allocation when airline i announces $b^{i;r}_m\ne v^{i;r}_m$ for all slots r in $\{1,\dots,R^i_m\}$:

$$
\bar{H}=\operatorname*{arg\,max}_{\left\{\left\{\{h^{i;r}_m\}_{r\in[1,R^i_m]}\right\}_{m\in[1,M^i]}\right\}_{i\in N}}\sum_{i=1}^{n}\sum_{m=1}^{M^i}\sum_{r=1}^{R^i_m}b^{i;r}_m\times h^{i;r}_m
$$

under constraints:

$$
\begin{cases}
\displaystyle\sum_{i=1}^{n}\sum_{m=1}^{M^i}\sum_{r=1}^{R^i_m}\sum_{a=1}^{A^{i;r}_m}\left(h^{i;r}_m\times\mathbf{1}_{s\in\mathcal{Y}^{i;r}_{m;a}}\times\mathbf{1}_{t=t^{i;r}_{m;a}}\right)\le k_{s;t},\ \ \forall s,\forall t, \\[12pt]
h^{i;r}_m\in\{0,1\},\ \ \forall i,\forall m,\forall r, \\[6pt]
\displaystyle\sum_{r=1}^{R^i_m}h^{i;r}_m\in\{0,1\},\ \ \forall i,\forall m.
\end{cases}
$$

Given that airlines' values are private and independent, airlines announce only one bid by slot and their bids are not functions of the other airlines.

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Then, vector $\hat{L}(i; m)$, solution of the program (9), does not change and the airline i's net surplus is:

$$S\left(\tilde{H}\right) = \sum_{r=1}^{R_m^i} v_m^{i;r} \times \tilde{h}_m^{i;r} - \left(\sum_{j=1}^{n} \sum_{m'=1}^{M^j} \sum_{r=1}^{R_{m'}^j} b_{m'}^{j;r} \times \hat{l}_{m'}^{j;r}(i; m) \right.$$

$$\left. - \left(\sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_{m'=1}^{M^j} \sum_{r'=1}^{R_{m'}^j} b_{m'}^{j;r'} \times \tilde{h}_{m'}^{j;r'} + \sum_{\substack{m'=1 \\ m' \neq m}}^{M^i} \sum_{r'=1}^{R_{m'}^i} b_{m'}^{i;r'} \times \tilde{h}_{m'}^{i;r'} \right) \right) \quad (11)$$

We compare the two net surplus (10) et (11):

$$\Delta S = \left(\sum_{r=1}^{R_m^i} v_m^{i;r} \times \hat{h}_m^{i;r} + \left(\sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_{m'=1}^{M^j} \sum_{r'=1}^{R_{m'}^j} b_{m'}^{j;r'} \times \hat{h}_{m'}^{j;r'} + \sum_{\substack{m'=1 \\ m' \neq m}}^{M^i} \sum_{r'=1}^{R_{m'}^i} b_{m'}^{i;r'} \times \hat{h}_{m'}^{i;r'} \right) \right)$$

$$- \left(\sum_{r=1}^{R_m^i} v_m^{i;r} \times \tilde{h}_m^{i;r} + \left(\sum_{\substack{j=1 \\ j \neq i}}^{n} \sum_{m'=1}^{M^j} \sum_{r'=1}^{R_{m'}^j} b_{m'}^{j;r'} \times \tilde{h}_{m'}^{j;r'} + \sum_{\substack{m'=1 \\ m' \neq m}}^{M^i} \sum_{r'=1}^{R_{m'}^i} b_{m'}^{i;r'} \times \tilde{h}_{m'}^{i;r'} \right) \right) \quad (12)$$

As $\hat{H}$ is defined (program (8)), ΔS is positive.

Whatever are the other airlines' bids, it is a dominant strategy for an air link to bid truthfully for each slot of each air link relevant for her. Truthful bids constitute an equilibrium in dominant strategy. This mechanism is direct revealing.

An efficient mechanism is such that all goods are allocated to agents with highest values. An efficient allocation is the one defined by $\hat{H}$ (program (8)). We just show that airlines bid truthfully, then the final allocation is $\hat{H}$. This mechanism is also efficient.

B Interpretation of airlines' bids in the example

The first relevant slot for airline 1 is in fact for several links. Two flights from sectors s_1 and s_2 go to the airline's hub in sector s_4. From this point, two flights go to sectors s_3 and s_6. Airline 1's ability to pay for those four air links is 70 monetary units. The airline does not try to get slots separately, because a part of them could miss it and then effects of its hub would be reduced. Alternative slots for those air links are delayed. Abilities to pay decrease as flight hours are put back.

Airlines 1 and 2 are in competition for a part of their first air link: sector s_1, s_6 and s_4. If its first choice is not satisfied, airline 2 prefers to bypass the congestioned sector, by crossing s_5. Due to the over-cost with this route, the ability to pay for this second choice is equal to 5 monetary units less than to the first one.

Airline 3's bid is for several flights between two airports. One takes off during the period t_1 for the air link s_4-s_5, and then it comes back. The same slot takes into account the two air links, because if the first does not begin at t_1, the second air link is necessary delayed. The second choice for this round-trip is postponed. For the third choice, the slot is so delayed that the return is canceled. It is the reason why the ability to pay for this slot is so low compared to the others: 20 monetary units instead of 52.

Airlines 1 and 3 compete for their second air link: sectors s_2 at t_1 and s_1 at t_2. Airline 3's value is the highest.

Sectors s_3 and s_6 at t_1 is common for air links of airlines 2 and 4. Each slot is made of a different complementary component for the two. For the whole slot airline 2's value is the highest, with 20 monetary units.

Sector s_4 at t_1 is asked four times. But sector capacity is equal to two flights. This over-demand will lead to allocation of slots which are not "favorite" slot.

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Aircraft Noise Perception Study in Brazil: A Perspective on Airport Sustainable Growth and Environmental Awareness

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ABSTRACT

Aircraft noise perception is related to several variables that are tangible and objective, such as the number of operations, flight schedules. Other variables, instead, are more subjective, such as preferences. However, although their elusiveness, they contribute to determine the individuals' perception of this type of externality.

Despite the fact that the complaints related to aeronautical noise have been registered since the decade of 50, it has been observed that the perception of noise seems to have grown, especially since the 80's. It has been argued that this change in noise perception has its roots on the accelerated expansion of air traffic. But, it is necessary to point out the important role played on modeling preferences, by the growing environmental conscience and the higher welfare and quality of life standards and expectations.

In that context, the main objective of this paper is to study the aeronautical noise perception in the neighborhoods of the Aeroporto Internacional de São Paulo – AISP (the biggest airport of South America). Specifically, it analyzes the relationship between aircraft noise perception and social class, which is expected to be positive.

Since noise perception is an intangible variable, this study chose as a proxy the value losses of residential properties, caused by aeronautical noise. The variable social class has been measured utilizing average per capita income of the population who live nearby the airport. The comparison of both, the lowest and the highest social class suggests that the relationship between social class and noise perception is positive in the AISP region. Moreover, it was observed that all social classes are very susceptible to aircraft noise annoyance. In fact, the magnitude of the noise perception proxy for both social classes -the residential value losses- was found to be comparable to levels encountered in developed countries.

Additionally, this paper highlights the aviation noise problem taken into account a scenario where the airport capacity may duplicate in the next 20 years. This scenario is

compounded by the paradigmatic change on environmental awareness that has emerged all over the world, as a result of the changing social and economic preferences, which favors human quality of life and a sustainable growth, in order to preserve resources endowments and quality of life for future generations. Under these circumstances, it can be foresighted that the social change is for the internalization of environmental problems, with the expected increase in the air transport sector costs.

Keywords: Aircraft noise perception; externalities; air transport.

1. INTRODUCTION

The aeronautical noise has been considered one of the most serious environmental problems of aviation, in accordance with the Report *The Full Cost of Intercity Transportation* (University of Berkeley, 1996).

Noise generated by aircraft operation affects negatively the quality of life of people living nearby airports. That notion of quality of life is a very subjective experience, as it is the aircraft noise problem (Janic, 1999). In fact, the evaluation of noise is also a subjective measure, because it depends on individual's noise perception, which depends on both tangible factors, such as numbers of landing and take-off aircraft operations, flight schedules, climatic conditions, and intangible factors, such as environmental awareness, welfare and quality of life standards, levels of education and income (Janic, 1999; Garcia, 1993).

Despite of the fact that the complaints related to aeronautical noise have been registered since the decade of 50, it has been observed that the perception of noise seems to have grown, especially since the 80's. It has been argued that this change of noise perception has its roots on the accelerated expansion of air traffic. But, it is necessary to point out that the perception of noise annoyance may have grown as a result of the increasing environmental awareness brought about by the institutionalization of environmental movements (Mol, 1999). Under these circumstances, the emergence of the ecological conscience has been accompanied by the emergence of higher standards and expectations about people's welfare and quality of life (Mol, 1999; Garcia, 1993). Moreover, it should be pointed out that these changes on welfare expectations have disseminated all over the world. The growing importance of such intangible factors might be credited in large measure to the web infrastructure that connected the world since the 80's and allowed access to new flows of information and knowledge created around the world.

For all these reasons, it has been observed an increasing social demand for noise reduction in the whole world. These changes on preferences have stimulated researches devoted to the evaluation of the human being perception of noise discomforts. This evaluation is complicated, because it involves personal attributes, such as sex, age and social class (Rogerson, 1995). Despite the difficulties associated to the noise perception evaluation, it should be emphasized the importance of obtaining an approximated measure of the externality. Thus, it would be possible to approach more adequately the problem of cost internalization. In fact, the idea is to understand the problem of noise perception in order to propose solutions that could improve human welfare and quality of life.

Additionally, this paper highlights the aviation noise problem taken into account a scenario where the airport capacity may duplicate in the next 20 years. This scenario is compounded by the paradigmatic change on environmental awareness that has emerged all over the world, as a result of the changing social and economic preferences, which favors human quality of life and a sustainable growth, in order to preserve resources endowments and quality of life for future generations. Under these circumstances, it can be foresighted that the social change is for the internalization of environmental problems, with the expected increase in the air transport sector costs.

2. AIRCRAFT NOISE PERCEPTION

When considering the evaluation of aircraft noise impact, most methodologies leave out the individual perception of noise annoyance, considered to be the size of the externality. Because of the important subjective characteristics of noise perception, its study becomes more dificult. It should be remember that there is a diference between emitted noise and perceived noise. The emitted noise, more easily quantifiable, is related to factors like the technological stage of the aircraft that is in operation, climatic and topographic condition, etc. On the other hand, noise perception is recognized to be a subjective experience, determined in large measure by subjective variables, which have been associated to personal attributes, such as sex, age and social class (Rogerson, 1995).

It is important to point out that Garcia found out that noise perception varied with social class. Thus, it can be expected that people that could be classified into higher classes are, in general, more refined and have higher quality of life standards. Therefore, it can be expected that they are less willing to accept aviation noise annoyance. Conversely, the lower class people would be less susceptible to noise. This situation is confirmed in the research developed in Finland by Heinonen-Guzejev et al. (2000), where he shows results that support that the self-report of noise sensitivity does not have a positive correlation with the people noise exposure.

In this context, it is interesting to study the subjective factors that determine aircraft noise perception, in order to provide subsidies for mitigating and controlling its environmental impacts.

3. THE ECONOMIC COSTS OF NOISE ANNOYANCE

Aviation noise affects negatively welfare of people living nearby airports. These effects are considered to be economic externalities. According to Nicholson (1985), externalities happen when two or more economic agents produce effects on the activities of each other and these activities are not visible in market transactions.

When a consumer buys economic goods, he causes an increase on its price, because this action determines a demand increase of such goods. This action is harmful for the remaining consumers. These effects, which are captured by the price system, cannot be characterized as externalities, because they do not reduce the market capacity of allocating resources efficiently. The price increase of a commodity reflects the society preferences for

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it. This price increase helps to recover the market equilibrium, by searching for an efficient resources allocation. Nevertheless, Nicholson (1985, pp. 285-287) states that "this is not the case for toxic chemical discharges, aircraft noise or trash."

In such cases, the market prices (of chemical products, air transportation or trash removal) may not reflect strictly the society preferences for these activities, because they are not likely to take into account the losses caused to third parties.

As it can see in Figure 1, once an externality does exist, the production of an economic good, that generates that effect, will be represented by Q_1. In this case, the Marginal private Benefit will be smaller than the Marginal Social Cost, generating an external diseconomy. On the other hand, when the external cost is considered, production is reduced to Q_2, optimizing the resources allocation.

Notice that the non-internalized cost of externalities increases the quantity produced. Therefore, the air transport user receives the benefits from the supply increase, as long as the community living in the airport noise area, which, in general, does not use this service, is jeopardized by the increase in output.

The correct understanding of the aviation noise externality is a fundamental requisite for developing an efficient economic instrument, capable to internalize the external costs.
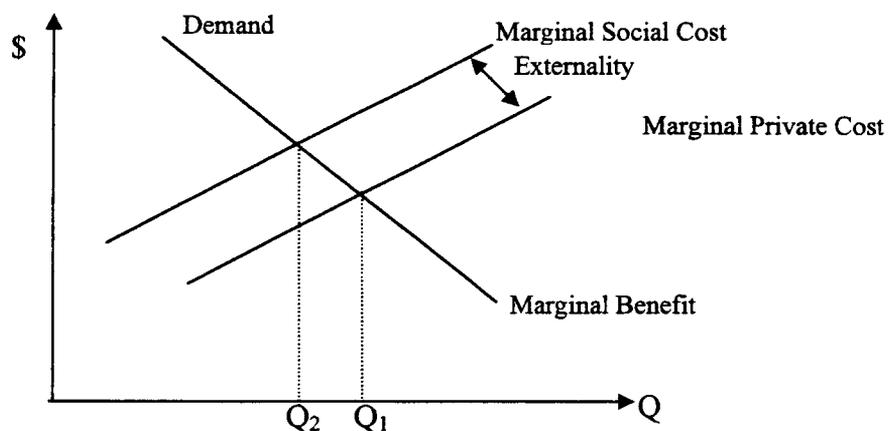
Figure 1 – Externality effect over the quantity produced

4. THE ECONOMIC REGION OF THE AISP/GRU

Aircraft noise perception is a localized experience. In fact, the socio-economic characteristics of the region surrounding the airport, as well as the airport's dimension, are factors that are expected to affect the perception of aviation noise discomfort. Thus, this part of the paper is devoted to describe the main socio-economic characteristics of the Guarulhos city and of the AISP/GRU.

4.1 – Guarulhos City characteristics

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The city of Guarulhos is located in the State of São Paulo, in the southeast region of Brazil. It has 1.100.000 of inhabitants and has the 3rd budget of the State. Despite this favorable position in the public finance context, a study developed by the Brazilian Institute of Geography and Statistic (IBGE), point outs that 22% of the population of Guarulhos can be classified under the poverty income line. Thus, they probably have no access to employment, or sufficient conditions of housing and food. The average per capita income is considered to be low when compared with the national average Gross Domestic Product - GDP. In fact, Guarulhos's average income is R$ 500,00 (five hundred reais) by month or about US$ 170[1], while the Brazilian average per capita Gross Domestic Product - GDP is about R$ 420,00 per month (IBGE, 2000).

The Guarulhos' unemployment problem is the result of structural changes suffered by declining industrial regions. This decline was caused in large measure by the "fiscal war" initiated by other Brazilian regions with the objective of attracting industries. In fact, Guarulhos observed the transferring of its industries to other regions of the country, mainly the northest, because of better fiscal conditions.

Another interesting characteristic derived from the city's historical industrial vocation is the population syndicate engagement, with popular presence in the political and classes fight. For this reason, despite the fact that the unemployment level could lead to the conclusion that people living in Guarulhos have low access to education and information, it is more probable that they have conditions to understand the social and economic processes that affect them. Thus, it is possible to expect them to organize themselves in order to fight for higher quality of life standards.

Guarulhos city is part of São Paulo metropolitan region, one of the largest cities of the world[2], which historically received enormous immigration flows. In that context, Guarulhos is a suburban area, which has been characterized for receiving part of those immigrants, especially from the poorest parts of the country, with the consequent irregular occupation. Also, even considering the fact that São Paulo's immigration flows have decline in intensity overtime, currently Guarulhos urban density is affected by São Paulo's own vegetative population growth, which pressures suburban areas.

Figure 2 expresses visually the urban demographic growing vector that comes from São Paulo City to the Airport region and increases substantially the demographic density of the airport's western borders. This situation is relevant environmentally because that region is right below the flight tracks of the most occupied runways. For this reason, it is expected that as both the urban demographic density and the airport expands, the aircraft noise problem worsen.

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[1] At the exchange rate of R$2,95/US$ 1 (O Estado de São Paulo Newspaper, www.estado.com.br, in 04/06/2003)

[2] São Paulo metropolitan region is estimated to have around 18 million inhabitants (IBGE, in http://www6.prefeitura.sp.gov.br/secretarias/planejamento/sp_em_numeros/0006).

INHABITANTS BY HECTARE

Habitantes por Hectare
- [ ] 0 - 15
- [ ] 16 - 62
- [■] 63 - 98
- [■] 99 - 123
- [■] 124 - 175

Elaboração: SIGeo
Fonte: IBGE - Censo 2001
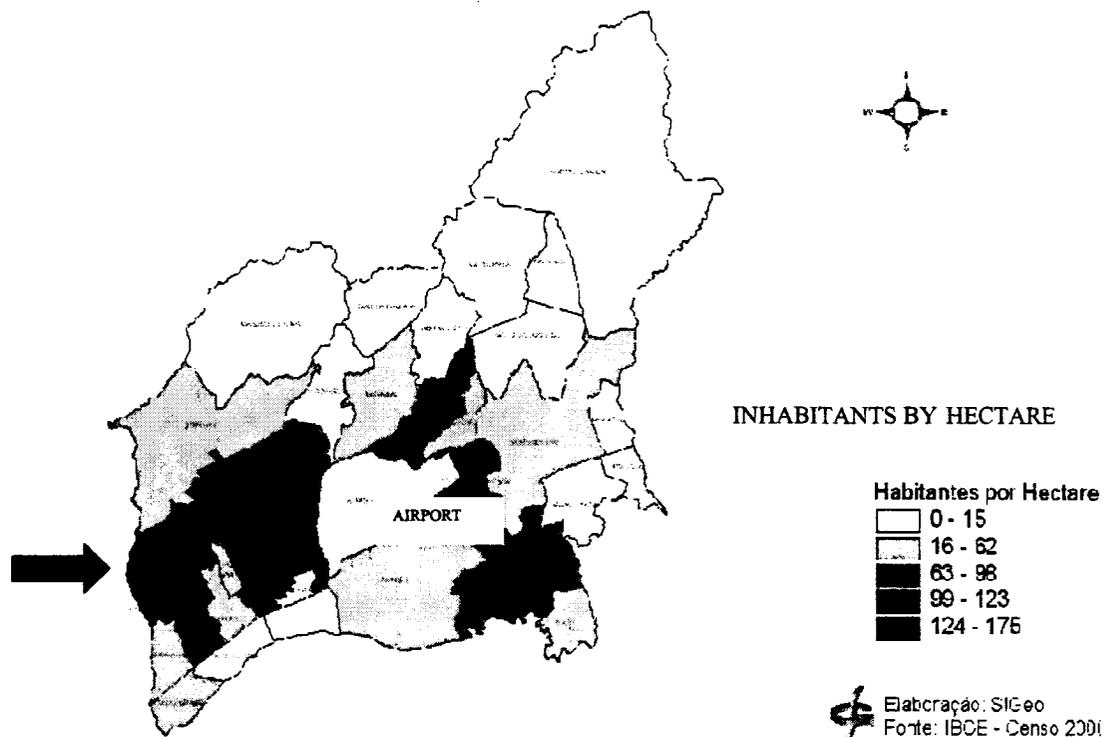
Figure 2: The urban demography of São Paulo Metropolitan Area and the AISP Region

It should be pointed out that there is a regulation designed to reduce noise problems in airport neighborhoods. Specifically, in the noise contour areas land use is not permitted without appropriate noise insulation, or even land use is simply not recommended. However, the combination of population vector growth with irregular land occupation turns noise regulations irrelevant because they are not respected. To compound this situation, there is a lack of integration between the regulation made by Brazilian civil aviation authorities (*Plano de Zoneamento de Ruído*) and the one made by the County's urban specialists (*Plano de Zoneamento Municipal*), which was more affected by population pressures than for environmental problems.

4.2 The Aeroporto Internacional de São Paulo (AISP/GRU)

The AISP/GRU, the biggest airport of South America, was inaugurated in January 20th, 1985 and has two parallel runaways with its centerlines separated from each other of 375m. The airport is located in the city of Guarulhos, 25 kilometers away from the city of São Paulo. It occupies an area, of its own property, equivalent to 14 km² (fourteen square kilometers). The airport passenger's throughput (embarked plus disembarked) was 11,000,000 in round figures during the year 2002.

The airport has an average daily traffic about 500 operations, 90% of which occur in runways 09L and 09R. The airport typical aircraft fleet is classified in the Chapter 3 of the ICAO Annex 16 (IAC, 1998).

5. AIRCRAFT NOISE PERCEPTION AT THE AISP/GRU

This part of this paper is devoted to study aircraft noise perception in the vicinity of the Aeroporto Internacional de São Paulo (AISP/GRU). Initially, it is described the research methodology employed in this study. Afterwards, results are presented and analyzed.

5.1 Research Methodology

The idea is to study the aeronautical noise perception, focusing the relationship between aircraft noise perception and social class, which is expected to be positive. The problem that arises in this study is that the noise perception is intangible, difficult to quantify. Therefore, it is necessary to find a variable that expresses noise perception in a quantifiable way. Thus, this study chose the variable, developed by Eller (2000), which is the losses of value of the residential properties, caused by aeronautical noise as a "measure" of the perceived noise discomfort. The variable social class was measured utilizing the average per capita income of the people who live nearby the airport.

It is interesting to comprehend the methodology utilized by Eller (2000) to asses the impact of aircraft noise on property values, assuming that such impact is closely related to the subjective noise perception variable. Thus, it is necessary to point out that the author's methodology was based on the ideas exposed by Frankel Marvin in a study carried out in 1991, where he interviewed real state developers in order to get the "real" market values. According to Marvin, the sample composition is important, and he recommends that qualified professionals, who have relevant market information, must be chosen to be interviewed[3]. Thus, Eller's research developed questionnaires, in order to interview real state developers, who worked in the Guarulhos city area[4].

Eller's study focused uniquely on the value losses of residential properties, because it was considered that noise impact is perceived in a different way by owners of commercial and residential properties. This differentiated perception can be explained by the fact that commercial properties are, in general, occupied during day light hours only[5].

The variable property value losses, chosen as a proxy of aircraft noise perception, was related to a variable that expresses social class. The social class variable requires also the choice of a "proxy" measure. Thus, this study chose the average per capita income as an

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[3] Additionally, the use of a sample of real state professional is considered to be appropriate due to the fact that other methods of assessing properties values –like researching official statistics or interviewing the properties owners – could fail to estimate these values, because they can incorporate other factors, not necessarily related to the airport influence (e. g., cemeteries, schools, highways and personal impression.)

[4] Eller's research developed Non Personal interviews made by means of questionnaires sheets, sent by postal shipment. This method is considered appropriated by Breen & Blankenship (1991), who recommended that the research universe should be homogeneous and small, as well as, the subject of investigation should be presented, in an identical and simple way, to all the interviewed people. It has to be pointed out that the method chosen by Eller allowed to previously identify the entire interviewed public, as well as to know in advance their postal addresses.

[5] Two factors that recommend the commercial properties exclusion from the sample refer, on one hand, to the fact that this type of property have a functional noise background that minimize the perception of the environmental noise, along with the fact that it can be easily insulated acoustically. The other factor that supports its exclusion is the expectation of oversized market values for commercial properties, due to their closeness to the airport area (this situation would typically affect business related to airport activities, like warehouses).

expression of social class. It could be argued that this variable is not the best to assess economic and social welfare, because those are elusive factors[6]. Despite these factors, this study assumes that average per capita income of the population who live nearby the airport is an appropriated measure of social class. There were utilized four social classes, based on published data.

It was necessary to remember that, amog the questionaires properly answered, there was not any of them that pointed out losses in property value from regions which average per capita income below the average of the city. It is explained by the fact that the poor regions of the city are located out of the aircraft noise impacted area, as it was already shown.

5.2 Results Analysis

The results[7] obtained by Eller (2000) were separated by property's value losses intensity, and for region. Thus, it was possible to associate each real state business region with its property's value losses intensity[8]. Afterwards, it was identified average per capita income for each real state business region. Therefore, it was possible to associate value losses intensity with social classes, as shown in Table 1.

Table 1: Properties market losses due to aircraft noise related to the average per capita

AVERAGE PER CAPITA INCOME (Reais)	PROPERTIES MARKET LOSSES			
	BELOW 10%	BETWEEN 11 AND 20%	BETWEEN 21 AND 30%	HIGHER THAN 30%
500-1000	0	50	50	0
1000-2000	0	33	35	32
2000-3000	0	33	25	42
>3000	6	30	23	41

income

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[6] It could be argued that economic and social welfare could be better expressed by a measure of the income purchasing power, however, due to the data scarcity this study chose a simple measure. Another variable that could be used is the educational level of people living nearby the airport, because there is a close relation between social class and human capital accumulated, but the data is not sufficiently discriminated.

[7] In this study, the results selected, corresponding to 99% of the responses, showed market losses above 11%.

[8] All the real state market regions were identified and, after that, the corresponding average per capita income of each region was found.

Considering that the "really" poor people do not live nearby the most noise-affected area, the lowest level of income selected was R$ 500 (five hundred Reais) per month, which is equal to the average income of the Guarulhos City.

The sample was classified in four income classes, and the people belonging to each social class was separated utilizing the noise perception criterion, as shown in Table 1. There, it can be observed that all social classes had losses of value estimated to be above 11% of the market value of a similar residential property located in an area not affected by noise. Moreover, between half and two thirds of the people, classified in each social class, had residential value losses greater than 20% of the market value of similar houses, located in a noise-free area. In fact, for income levels above R$1000, around 67% of the income level sample group declares residential value losses of more than 20%. It is interesting to note that people classified into the lowest income class registered substantial losses of value in their residential properties. However, as expected, the highest income class had more residential properties losses, indicating that their noise perception was greater.

Table 1, also, shows that for the lower noise perception level, there were reported only 6% of the sample groups earning above 3000. Another interesting feature of the sample is that people classified into the lowest income class registered intermediate levels of noise perception, as approximated by the range of residential value losses between 11% and 30%.

Also, it is possible to observe, in the second column of Table 1, that all social classes earning above R$1000 registered around a third of the group sample on the intermediate noise perception levels, reporting properties market losses between 11% and 20%. On the other hand, for the subsequent intermediate noise perception level, it was observed that the proportion of the sample that reports between 21% and 30% declines as income increases. However, as expected, for the higher noise perception level, the proportion of people affected, in each social class, increases as income increase.

Additionally, it is possible to look at Table 1 from a diagonal perspective, so as to allow both noise perception and social level to increase. Thus, it is observed that higher income levels reported a substantial proportion of people (around 40%) very much affected by aircraft noise. As commented above, results for one of the intermediate levels, again, do not follow the expected pattern. However, observing results for social classes that earn more than R$1000 and comparing both the more susceptible group and the lower intermediate level, it can be clearly perceived a positive relationship between noise perception and income class.

Thus, it was observed that the lowest income class registered substantial losses of value in their residential properties. Also, as expected, it was observed that the higher income class had proportionally more reports of residential properties losses, indicating that their noise perception was greater. Thus, the comparison of both, the lowest and the highest social class suggests that the relationship between social class and noise perception is

positive in the AISP region. However, since part of the sample, reflecting one of the intermediate noise perception levels, did not behave as expected, it is recommended to pursue this study, in order to better support the conclusion that social class determines aircraft noise perception. Additionally, an important result obtained by this study is the fact that all social classes are very susceptible to aircraft noise annoyance. In fact, the magnitude of the noise perception proxy for both social classes -the residential value losses- was found to be comparable to levels encountered in developed countries.

Thus, the results obtained in this study highlighted the change on the behavioral pattern, since both, the lower and the upper, social classes perceived noise as a serious problem. These modifications on perception could be attributed to a change on social preferences caused by the emergence of new global vision of what is a good quality of life.

6. ENVIRONMENT AWARENESS AND AIIRPORT SUSTAINABILITY

This part of this paper is devoted to study the evolution of environmental awareness over time, as supported by the new information and knowledge economy, and its expected impacts on the AISP/GRU expansion plans.

6.1 Expected AISP/GRU Growth

As mentioned above, the AISP/GRU, the biggest airport of South America, was inaugurated in January 20th, 1985 and has two parallel runaways. According to Infraero (Apud Lorenço, 2003, 44), these two runways support around 14 million passengers annually.

Table 2 shows that airport has already reached its full planned traffic capacity. Thus, it is expected an airport expansion, as was planned by the Infraero Director Plan[9].

Table 2: Annual Movements of Passengers (embarqued + disembarqued) at the AISP/GRU

YEAR	TOTAL
1995	10.704.421
1996	14.032.208
1997	14.407.036

Font: IAC (Apud Lorenço, 2003, 44)

In fact, nowadays there is a project to build the 3rd runway. This runway is planned to allow movements of 12 million passengers annually. Thus, the AISP/GRU full capacity will reach 26 million passenger movements per year.

Lorenço (2003) estimated that the AISP would reach full capacity of the three runways close to 2014. Thus, table 3 shows his estimates, which were based on other Brazilian studies, focused on projecting the airport capacity demand, under alternative scenarios. There were chosen two year bases in order to avoid any abnormal situation.

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[9] Infraero is a government agency responsible for Brazilian airports management.

Table 3: Alternative Scenarios for Annual Movements of Passengers at the AISP/GRU

SCENARY	PROJECTED DEMAND	YEAR (Base: 2002)	YEAR (Base: 2000)
Infraero IAC- Mean	26.034.000	2014	2012
IAC – Pessimistic	26.727.000	2015	2013
PDDT – Pessimistic	26.315.000	2014	2013

Font: Lorenço (2003, 50)

The relevant aspect of this discussion is that in the next decade the AISP/GRU will duplicate its capacity in around one decade, and that situation will have a very important impact on the environment.

6.2 Preferences Changes And Environmental Awareness

Airports managers have to be prepared to face an increasing social demand for reducing environmental problems, specifically the aviation noise annoyance. That change in social demand could be the attributed to the emergence of a more susceptible environmental awareness, in large part because of the changing preferences in a global scale. Such changes favor human quality of life and a sustainable economic development, in order to preserve resources endowments for future generations. Thus, these new set of social and economic preferences configures itself in a new paradigm[10], because it brings new values and perceptions about what is acceptable, about what brings welfare.

This paradigmatic change in human preferences could be attributed to the important spaces opened in economic life of modern societies, by the ecological movements that initiated during the 70's. According to Mol (1999), the old radical movements have transformed into institutionalized movements, which have a saying in economic decisions that affect environment. Mol calls this process of ecological modernization.

The ecological modernization brought about the institutionalization of environmental regulation and control. Thus, they participate in environmental negotiations and obviously have left behind their radical positions, accepting some environmental losses in exchange for ecological advances, when internalization costs were too heavy.

Ecological movements have contributed to create a new ecological conscience all around the world. In fact, the global emergence of environmental awareness was expressed in the World Submit of Rio de Janeiro in 1992. The idea was to define an agenda in order to avoid ecological risks and environmental deterioration. Thus, this first meeting can be seen as the foundation of a world movement that supports the preservation and recuperation of the environment.

It is necessary to point out that the perception of noise annoyance may have grown as a result of the increasing environmental awareness. Thus, these considerations may shed

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[10]Paradigm can be defined as the set of values that defines the perception and the vision of the world (Capra, 1982).

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a light on the results obtained in this study, which showed that noise perception intensity was not differentiated by social class. In fact, both the higher and the lower income classes perceived aircraft noise as a negative externality.

6.3 The Knowledge Economy and Environment

The growing importance of environmental factors in determining human preferences and welfare standards might be credited in large measure to the information and communication technology innovations implemented during the 90's, in a worldly scale. In fact, in this period the world became connected by a digital web, which allowed to accessing the flows of information and knowledge created around the world.

These new communication technologies had a very important impact on the rate of innovation generation and adoption by the productive sector of the economy. The access to enormous flows of new knowledge contributes itself to generate new ideas, new knowledge. In fact, this times are inaugurating a new economic paradigm, where the main factor in the production function is new knowledge, which itself helps to generate the most valuable type of products –knowledge-intensive goods and services.

Some of these innovations could alleviate environmental problems, such as the developments of less noisy aircrafts turbines. These innovations might be the result of changing world preferences toward higher standards of life. One indication of the importance of these social pressures in molding entrepreneur's decisions could be found in the NASA strategic planning for the next 25 years. Thus, in the strategic goals roadmaps developed by Nasa, the third goal that guides their long run investment decisions is noise reduction. Specifically, the goal is to reduce the perceived noise levels of future aircraft by 1/2 (10dB) from today's subsonic aircraft within 10 years, and by 3/4 (20dB) within 25 years. Consequently, efforts will be devoted to develop technology to reduce community noise impact (www.nasa.gov).

Another side-effect of the new information and communication infra-structure that links the world is the fantastic access to information and knowledge it provides. This access creates conditions for expanding people's awareness of social, political, economic and ecological problems. Under these circumstances, the civil sector can be mobilized by Non Government Organizations in order to fight for their rights or their welfare.

The growing expansion of the third sector could be seen as a result of the strengthen communication web, which reduced enormously the costs of informing and contacting people. As an example of this potential for people mobilization created by today's technologies, it can be pointed out the case of pacifists movements that have spurred all around the world recently.

As pointed out above, noise perception intensity is considered to be related to quality of life expectation, which is highly influenced by people's information/education level. In the case of AISP/GRU, which is located in a region, where people have more access to information because of their presence in the political and classes fight, the social demand for quality of life is expected to be stronger, even from people with low income. In these circumstances, results obtained in this study support the recommendation that government and airport authorities change the idea that poor people are less sensitive to

annoyance. Nowadays, as a result of higher access to information, the social demand for welfare is expected to increase, with the consequent development of a new relationship between airport and society.

6.4 The AISP/GRU Sustainable Growth

The emergence of new environment preferences supported by strengthen Non Government Organizations could be seen as a signal that airports managers would be, more and more, required to face pressures to reduce environmental externalities, which would require the adoption of measures that would increase airports costs.

Under this scenario, the AISP/GRU growth plan would be very much attacked by social and ecological movements, because it would worsen the already critical aircraft noise perception problem. Moreover, as the airport expands to double its current capacity, also the urban demographic density will increase in the regions nearby the airport. Thus, it can be expected that the perception of noise discomfort would become so relevant that may initiate social and political pressures that may limit AISP/GRU expansion. In fact, airport growth has to be sustainable in the long-run[11], so as to preserve environment. Under these circumstances, airport managers would have to deal with the internalization of the noise negative externality. That situation, besides increasing airport costs, would reduce its rate of growth because the social optimum airport capacity is below the private one.

This scenario could be attenuated by the expected technological advances devoted to aircraft noise reduction. However, airport expansion strategic planning can not omit environmental issues. In fact, as it can be foresighted that the social change is for the internalization of environmental problems, managers have to be prepared to deal with the expected increase in the air transport sector costs.

In this context, the implementation of isolated control/mitigation measures to deal with specific environmental problems may not avoid future social demands that might impair airport growth. Thus, it is suggested the development of a managerial program for dealing with environmental problems at the AISP/GRU.

8. CONCLUSIONS

The last decade was characterized by the emergence of worldwide webs that linked the world and allowed to accessing enormous flows of information and knowledge. Under these circumstances, citizens of the world are more conscious of the serious implications of neglecting environmental impacts on the world ecology sustainability. As a result, during the last years, a new approach toward these problems has resulted in social pressures to develop regulation and to implement measures designed to mitigate/control environmental damages on social and economic welfare, caused by economics activities. This situation demands that airport managers and aeronautical engineers take into account possible environmental negative impacts, when they develop airport expansion projects. Moreover,

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[11] Sustainable growth is the kind of growth that is compatible with the preservation of the ecology and of the resource endowments for the use of future generations. In other words, sustainable economic growth does not compromise future generation's economic growth (Seroa da Motta, 1997). In this case, sustainable growth is associated to the microeconomic growth decisions that are compatible with social demands for the preservation and recuperation of the environment, in the long-run. Under these circumstances, firm's economic growth decisions do not compromise the long-run expansion path of the firm.

it is expected that managers develop a more systemic view of the relationships between airport and society.

In this context, the main objective of this paper was to contribute to the understanding of environmental problems in the Brazilian air transport sector. In this context, this study analyzed aeronautical noise perception in the neighborhoods of the Aeroporto Internacional de São Paulo – AISP (the biggest airport of South America). Specifically, it focused on the relationship between aircraft noise perception and social class, which was expected to be positive.

This work contributed to show that Brazilian preferences support the reduction of environmental negative impacts, caused by aircraft noise. Thus, it was observed that the lowest income class registered substantial losses of value in their residential properties. As expected, the higher income class had more residential properties losses, indicating that their noise perception was greater. Thus, the comparison of both, the lowest and the highest social class suggests that the relationship between social class and noise perception is positive in the AISP region. However, since part of the sample, reflecting one of the intermediate noise perception levels, did not behave as expected, it is recommended to pursue this study, in order to better support the conclusion that social class determines aircraft noise perception. Additionally, an important result obtained by this study is the fact that all social classes are very susceptible to aircraft noise annoyance. In fact, the magnitude of the noise perception proxy for both social classes -the residential value losses- was found to be comparable to levels encountered in developed countries.

Moreover, this paper highlighted the aviation noise problem taken into account a scenario where the airport capacity may duplicate in the next 20 years. This scenario was analyzed taken into account also the paradigmatic change on environmental awareness that has emerged all over the world. Thus, social and economic preferences favor human quality of life and a sustainable growth, in order to preserve resources endowments and quality of life for future generations. Therefore, it can be foresighted that the social change is for the internalization of environmental problems, with the expected increase in the air transport sector costs.

Under these circumstances, airport expansion strategic planning can not omit environmental issues. Moreover, the recommendation is for the development of a managerial program, capable of dealing with environment problems in a systemic way, so as to allow a sustainable airport growth in the long run.

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The Carrier's Liability for Damage Caused by Delay in International Air Transport

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Abstract

Delay in the air transport occurs when passengers, baggage or cargo do not arrive at their destination at the time indicated in the contract of carriage. The causes of delay in the carriage of passengers are booking errors or double booking, delayed departure of aircraft, incorrect information regarding the time of departure, failure to land at the scheduled destination and changes in flight schedule or addition of extra landing stops. Delay in the carriage of baggage or cargo may have different causes: no reservation, lack of space, failure to load the baggage on board, loading baggage on the wrong plane, failure to off-load the baggage or cargo at the right place, or to deliver the covering documents at the right place.

The Montreal Convention of 1999 Article 19 provides that 'The carrier is liable for damage occasioned by delay in the carriage by air of passengers, baggage or cargo. Nevertheless, the carrier shall not be liable for damage occasioned by delay if it proves that it and its servants and agents took all measures that could reasonably be required to avoid the damage or that it was impossible for it or them to take such measures'.

The Montreal Convention Article 22 provides liability limits of the carrier in case of delay for passengers and their baggage and for cargo. In the carriage of persons, the liability of the carrier for each passenger is limited to 4,150 SDR. In the carriage of baggage, the liability of the carrier is limited to 1,000 SDR for each passenger unless a special declaration as to the value of the baggage has been made. In the carriage of cargo, the liability of the carrier is limited to 17 SDR per kilogram unless a special declaration as to the value of the cargo has been made.

The Montreal Convention Article 19 has shortcomings: it is silent on the duration of

the liability for carriage, and it does not make any distinction between persons and good. It does not give any indication concerning the circumstances to be taken into account in cases of delay, and about the length of delay. In conclusion, it is desirable to define the period of carriage with accuracy, and to insert the word 'unreasonable' in Article 19.

I. Introduction

Since 1929, air carriers have been carrying passengers, baggage and cargo on the basis of an aviation liability system which originated in the Warsaw Convention.

This system is about to change. In 1999, ICAO organized a diplomatic conference in Montreal, which agreed on the adoption of a new convention, called the Montreal Convention of 1999. This new convention is designed to replace the Warsaw Convention and all the amendments thereto so as to create a uniform aviation liability system. Its structure and provisions are based upon those of the Warsaw Convention, as amend, and other international agreement.

The Montreal Convention of 1999 with 29 ratifications as at April 2003, is expected to enter into force in 2003 upon the 30th ratification[1].

Considering that the air carrier's customer has chosen the carriage by air because of its speed and to save time, Article 19 of the Warsaw Convention and the Montreal Convention declares the carrier is liable for damage occasioned by delay in the carriage by air of passengers, baggage or cargo.

Delay occurs when passengers, baggage or cargo do not arrive at their destination at the time stipulated in the contract of carriage. The causes of delay in the carriage of passengers may be booking errors or double bookings, delayed departure of aircraft, incorrect information given to passengers regarding the time of departure, failure to land at the scheduled destination, and changes in the flight schedule or addition of extra land stops.

However, delay in the carriage of baggage or cargo may occur due to different causes, e. g. no reservation, lack of space, failure to load the baggage on board, loading baggage on the wrong plane, failure to off-load the baggage or cargo at the right place, or to deliver the covering documents at the right place[2].

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[1] Article 53(6) of the Montreal Convention provides that this Convention shall enter force on the sixtieth day following the date of deposit of the thirtieth instrument of ratification, acceptance, approval or accession with the Depositary between the States which have deposited such instrument.

[2] I. H. Ph. Diederiks Verschoor, "The liability for Delay in Air Transport", *Air & Space Law*, VolumeXXVI, Number6, November 2001, Kluwer Law International, p.300.

The Warsaw Convention does not provide a special limit of the carrier's liability for delay in the carriage of passengers, baggage or cargo, while the Montreal Convention of 1999 fixes a special limit of the liability for delay.

This paper intends to describe the liability regime of the carrier for delay in the international air transport under the Warsaw Convention and the Montreal Convention, comparing the differences between them. Also this paper deals with the issues of the Convention and conditions of carriage which are relevant for the liability of the air carrier for relay.

II. Causes of Flight Delays

As shown in Table 1 'the statistics of flight delays by airport of 2002' reported by the Korea Airports Authority,[3] the causes of delays of international flights in Korean airports are composed of weather, aircraft connection, aircraft maintenance, passenger processing, multiple causes, and others.

In this statistics of flight delays, standard for delay of international flight refers to delay of more than one hour, and multiple causes refer to the compound of aircraft connection, passenger connection, passenger processing, and ground waiting, and others refer to passenger connection, ground handling, runway, air traffic control, ground waiting, and aviation security, and weather refers to fog, snow, rain and others.

Among the causes of total delays of international flights in Korean airports, the ratio of delayed flights due to aircraft connection compared to the total international flights is 1.29% which is the biggest specific gravity, and the ratio of delays due to weather is 0.36%, the ratio of delays due to aircraft maintenance is 0.33%, the ratio of delays due to passenger processing is 0.05%, and the ratio of delays due to multiple causes is 0.001%, and the ratio of delays due to other causes is 0.40%.

Particularly, in Incheon International Airport opened on March 29, 2001, as hub airport in Korea, the ratio of delays due to weather is 0.31%, and the ratio of delays due to aircraft connection is 1.29%, and the ratio of delays due to aircraft maintenance is 0.34%, and the ratio of delays due to passenger processing is 0.05%, and the ratio of delays due to other

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[3] Korea Airports Authority, *Airport Traffic Report* 2002: http://www.airport.co.kr

causes is 0.45%.

<Table 1> International Flight Delays by Airport in Korea

2002. 1-2002. 12

Note: Excludes unscheduled and cargo flights.

Source: Korea Airports Corporation, *Airport Traffic Report* 2002:

http://www.airport.co.kr

III. Meaning of 'Delay in the Carriage by Air'

Article 19 of the Warsaw Convention and the Montreal Convention states that the carrier is liable for damage occasioned by delay in the carriage by air. However, the Convention provides no definition of delay.

Speed is an essential part of the carriage by air. In case of delay the carrier is liable according to the Convention, but according to case law and jurisprudence the delay must be 'unreasonable'.

The question of what is to be considered as 'unreasonable' delay will

Airport	Aircraft Movements	Weather	Flight Connection	Aircraft Maintenance	Passenger Processing	Multipule Causes	Other	Total
Incheon	97,045	309	1,257	335	54	0	442	2,397
Gimhae	11,764	70	123	30	2	1	5	231
Jeju	2,131	8	24	2	0	0	2	36
Daegu	1,489	10	44	8	1	1	4	68
Gwang-ju	565	3	7	1	0	0	0	11
Cheong-ju	511	9	17	2	0	0	9	37
Yang-yang	12	0	1	0	1	0	0	2
Total	113,517	409	1,473	378	58	2	462	2,782

depend on all sorts of circumstances, e.g. the distance of carriage, the manner in which the transportation is carried out, the weather conditions,

the season, the availability of other means of transport, etc.[4]

It is submitted that under the common law, in the absence of any express contract, the carrier is only bound to perform the carriage within a reasonable time having regard to all the circumstances of the case; accordingly, delay means failure to complete the carriage in a reasonable time.[5]

This rule, found in the cases on the carriage by land and sea, was applied to the carriage by air in *Panalpina International Transport Ltd. v. Densil Underwear Ltd.*[6] In the case the court, stressing that air transport is used because of its speed, held that a delay in the delivery of cargo to Nigeria, from 2 December to 21 December, leading to the loss of Christmas trade, was in the circumstances an undue and unreasonably delay.[7]

Several interpretations can be attributed to the phrase of 'delay in the carriage by air'. It can mean: (a) that the delay must occur whilst passengers, baggage or cargo are airborne, or (b) that 'carriage by air' in Article 19 must be read together with Article 18(2) which defines the period of liability for loss of, or damage to, any checked baggage or any goods, or(c) that liability for delay exists whenever passengers or goods do not arrive on time at the point of destination.[8]

The first and third interpretation have been rejected by the courts in several jurisdictions, while a number of cases have favored the second interpretation.[9] The courts have used the definition of 'carriage by air' in Article 18(2) to ascertain whether the delay had occurred during that period.

Article 18(2) defines the period of carriage by air of checked baggage or cargo as 'the period during which the baggage or cargo is in charge of

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[4] I. H. Ph. Diederiks Verschoor, *supra* note 2, p.301.

[5] Shawcross & Beamont, *Air Law*, Fourth Edition, Volume 1, Butterworth & Co (Publishers) Ltd., 1989, para. 192-193.

[6] [1981]1 Lloyd's Rep(QBD); Shawcross & Beamont, *supra* note 4, para. 192-193.

[7] *Ibid.*

[8] Georgette Miller, *Liability in International Air Transport*, Kluwer Law and Taxation Publishers, 1977, p.158.

[9] *Bart v. British West Indian Airways, Ltd.*, 23[1967] 1 Lloyd's Rep. 239(Guyana Ct. App. 1966); *Brunwasser v. Trans World Airlines, Inc.*, 10a, 541 Suppl388(WD Pa, 1982), 17 *Avi* 17,723.

the carrier, whether in an airport or on board an aircraft, or, in the case of a landing outside an airport, in any place whatever'; but the period does not extend to any carriage by land, sea or river performed outside an airport (Article 18(3)). This period includes time after the arrival of goods at the airport of destination.

The application of Article 18(2) to delay solves the problem for the carriage of baggage and cargo, but not for the carriage of passengers. It has been advocated that the delay in passenger cases should be ascertained by reference to Article 17, which defines the period of liability for the carriage of passengers.[10]

Article 17 does not expressly define the period of carriage by air of passengers, but refer to an equivalent period, referring to accidents taking place 'on board the aircraft or in the course of any of the operations of embarking or disembarking.

It is submitted that 'delay in the carriage by air' in Article 19 means delay during the period mentioned in Article 17 in the case of passengers, and means delay during the period mentioned Article 18 in the case of checked baggage or cargo.[11]

IV. Liability of the Carrier for Delay under the Convention

1. Limit of Carrier's Liability for Delay

The Warsaw Convention provides no special limit of the carrier's liability for delay in the carriage of passengers, baggage or cargo. So the same limit applies where the liability is based on delay as applies in cases of death or injury, and of loss or damage.[12] However, the Montreal Convention provides explicitly the limit of the carrier's liability for delay in Article 22: In the carriage of persons, the liability of the carrier for each passenger is limited to 4,150 SDR; In the carriage of baggage, the liability of the carrier is limited to 1,000 SDR for each passenger unless the passenger has made a special declaration of interest in delivery at

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[10] Georgette Miller, *supra* note 7, p.159.

[11] Shawcross & Beaumont, *supra* note 4, para.191.

[12] Article 22 of the Warsaw Convention provides that : in the carriage of passengers the liability for each passenger is limited to 125,000 francs(8,300SDR); in the carriage of checked baggage and cargo the liability is limited 250 francs(17SDR)per kilogram; in the unchecked baggage the liability is limited to 5,000 francs(332SDR).

destination and has paid a supplementary sum; In the carriage of cargo, the liability of the carrier is limited to 17 SDR per kilogram unless the consignor has made a special declaration of interest in delivery at destination and has paid a supplementary sum.

Under Article 22(5) of the Montreal Convention, the foregoing limit of the liability for delay in the carriage of persons and baggage does not apply if it is proved that the damage by delay resulted from an act or omission of the carrier, its servants or agents, done with intent to cause damage or recklessly and with knowledge that damage would probably result.

The carrier is liable without limitation for delay of baggage when his employer had specifically informed the passenger that his baggage was on board the aircraft while it had been removed therefrom and was delivered after the passenger had returned to his home at the end of the holiday, the misinformation having been given deliberately and recklessly.[13]

In *Oddvin Lokken v. Federal Express Corporation*[14] the court has held that an air carrier's failure to timely delivery an international shipment did not, without more, constitute willful misconduct under the terms of the Warsaw Convention. The shipper presented no evidence beyond speculation and conclusive assertions that would permit a jury to reasonably conclude that the carrier's failure to deliver the package resulted from willful misconduct. Consequently, the Convention governed the claim and limited the carrier's liability.

2. Exoneration of Carrier's Liability

The carrier is not liable for damage occasioned by delay if it proves that it and its servants and agents took all measures that could reasonably be required to avoid the damage or that was impossible for it or them to take such measures under Article 19 of the Montreal Convention.

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[13] Florida Court of Appeals, 3rd District, *Compania de Aviation Faucett v. Mulford*, 29 July 1980: 15 *Avi* 18,358.

[14] U. S. District Court, Southern District of New York, No. 99 Civ. 0585(THK), 16 February 2000: 27 *Avi* 17, 596.

The only way in which the carrier can be relieved of liability is to prove that he has taken all necessary measures to avoid the delay, or that it was impossible for him to take such measures. It is not enough for the carrier to prove that after the cause of delay had occurred, everything possible was done to minimize the damage. The carrier must prove that there was no negligence in the occurrence of the delay itself.

If the delay is caused before departure or after arrival by a through and lengthy inspection of the aircraft by the customs authorities, the carrier can not be held responsible. As the customs authority is not a servant or agent of the carrier, he can not take measures to avoid damage by delay.[15]

The carrier was held liable when part of the cargo arrived 17 days late and the carrier did not prove that he had diligently tried to have the goods carried on another aircraft or by another airline: 'considering that there exist many direct and indirect aerial links between Paris and Teheran, he has manifestly acted negligently and with complete disregard of his duties under the contract of carriage'.[16]

If the carrier proves that the damage by delay was caused or contributed to by the negligence or other wrongful act or omission of the person claiming compensation, or the person from whom he derives his rights, the carrier shall be wholly or partly exonerated from its liability to the claimant to the extent that such negligence or wrongful act or omission caused or contributed to the damage under Article 20 of the Montreal Convention.

Once the existence of damage due to delay is proved, the carrier is presumed to be liable on the basis of Article 19. The carrier can only escape by showing that he took the necessary measures to avoid the damage, or that it was impossible to take such measures, or that the damage was due to the contributory negligence of the injured person.

3. Carrier's Liability for Delay due to Overbooking.

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[15] Landgericht Frankfurt am Main, 14 November 1990; ZLW, 1991, p.188; Transp R, 1991, p. 146; *Air Law*, Vol. XVI, 1991, p. 142; I. H. Ph. Diederiks Verschoor, *supra* note 2, p. 306.

[16] Court of Appeals, Paris, *Iran Air v. Societe generale de Geophysique*, 14 November 1974: 1975 RFDA 60 ; Rene H. Mankiewicz, *The Liability Regime of the International Air Carrier*, Kluwer Law and Taxation Pubilishers, 1981, p.193.

Many airlines adopt the practice of overbooking flights to counter act 'no shows': passengers with bookings but who do not present themselves, so as to maximize seat-occupancy and to minimize the loss of revenue they would otherwise suffer.[17] Overbooking is one of the causes of delay, and it has become a rather common occurrence in the airline business these days.

The U.S. Courts have held that the carrier is liable for delay of an overbooked passenger, because his refusal to issue a boarding pass was in open violation of the carrier's own priority rules with respect to embarkation of overbooked passengers.[18]

A German court has held that the carrier is liable for any delay caused by his refusal to permit embarkation on the flight on which the passenger held a confirmed seat, whether the flight was overbooked or not.[19]

In *Carmia Fields v. Bwia International Airways Limited* [20] a claim for emotional injuries by a passenger who was denied boarding on an international flight to attend her father's funeral was preempted by the Warsaw Convention. The passenger asserted that the Convention was inapplicable because her claim arose the carrier's nonperformance of a contractual obligation. However, the carrier performed its obligations under the contract for carriage when it transported the passenger to her destination on later flight. Consequently, the Convention governed the claim because it arose from delayed transportation. Since the passenger alleged no physical injury or pecuniary loss as required for recovery under the Convention, the claim was barred.

The compensation on account of overbooking has been regulated in the EC and the U.S.A. In the U.S.A. the CAB laid down some rules, which were one of the sources for the later European Community rules to be based on.[21]

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[17] Shawcross & Beamont, *supra* note 4, para. 198.1.
[18] United States Supreme Court, *Nader v. Allegheny Airlines*, 7 June 1796: 14 *Avi* 17, 148; U.S. Court of Appeals, Seventh Circuit, *Karp v. North Central Air Lines*, 31 August 1978: 15 *Avi* 17, 355.
[19] Tribunal, Dusseldorf, 3 February 1971: ZLW 290, 293; Rene H. Mankiewicz, *supra* note 16, p.191.
[20] U.S. District Court, Eastern District of New York, No. 99-CV-2493(JG), 7 July 2000: 27 *Avi* 17,933.
[21] I. H. Ph. Diederiks Verschoor, *supra* note 2, pp. 303-304.

The EC rules issued on 4 February 1991 provide that: 'EC passengers are entitled to a certain sum to be paid by the air carrier in case of overbooking, a part from an additional to any compensation for damage caused by the ensuing delay'. In case of flights of 3,500 kilometers or under the amount set at ECU 150, for longer flights at ECU 300. These amounts are halved if the passenger is offered alternative transportation enabling him to arrive with a delay of no more two hours in respect of his original time of arrival, or four hours in case of flights of more than 3,500 kilometers.[22]

Towards the end of December 2001 the European Commission put forward a proposal for a regulation establishing common rules on compensation and assistance to air passenger in the event of denied boarding, cancellation and long delay of flights.[23]

Briefly, the proposal would extend rights given to passengers by the current regulation on denied boarding (Council Regulation 295/91) by imposing an obligation on airlines to call for volunteers in exchange for agreed benefits and increasing compensation some five times to € 750 for short-haul flights and € 1,500 for long-haul flights. It would also create similar rights and obligations in respect of cancellation of flights otherwise than because of exceptional circumstances beyond the airline's responsibility. Further, it would entitle passengers subject to long delays (i. e. of two or more in the case of short-haul flights and four hours or more in the case of long-haul flights) to choose between an alternative flight and reimbursement, and to special assistance in the case of disabled passengers.[24]

4. Timely Notice of Complaints

Under Article 31 of the Montreal Convention, in the case of delay, the complaint must be made at the latest within twenty-one days from the date on which the baggage or cargo have been placed at his disposal. Every complaint must be made in writing and given or dispatched within

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[22] Council Regulation No. 295/91; B.J.H. Crans and E.M.H. Loozen, "EC Aviation Scene", *Air Law*, Vol. XVI, 1991, Kluwer Law International, pp. 178-194.

[23] OJ No. C-103/E225, 30 April 2002.

[24] John Balfour, "EC Aviation Scene(No1:2002)", *Air & Space Law*, Volume XXVII, Number 4/5, September 2002, Kluwer Law International, p.250.

the times aforesaid. If no complaint is made within the times aforesaid, no action shall lie against the carrier, save in the case of fraud on its part.

In *Oddvin Lokken v. Federal Express Corporation*[25] a shipper's failure to provide an air carrier with timely written notice of loss incurred due to a delayed shipment warranted the dismissal of his claim under the terms of the Warsaw Convention. The shipper's alleged timely verbal notice to the carrier followed by a written notice delivered five months after the shipment was made was insufficient to satisfy the Convention's requirements. Accordingly, the shipper was barred from recovering damages arising from the delayed delivery.

V. Effect of Conditions of Carriage Excluding Carrier's Liability for Delay

The Montreal Convention recognizes the freedom of the parties to enter into a contract that may stipulate specific dates and times for the carriage by air in Article 27, but provisions or general conditions of carriage specifying conditions under which the carrier would be relieved in whole or in part of liability for delay are null and void under Article 26 of Montreal Convention.[26]

It is commonly provided in General Conditions of Carriage of the airlines that 'the times shown in timetable or elsewhere are approximate and not guaranteed and form no part of the contract of carriage, and schedules are subject to change without notice and the carrier assumes no responsibility for making connections'.[27]

A clause in the carrier's tariff which limits compensation for delay to the refund of the ticket price when the flight was cancelled for technical reasons, is invalid and unenforceable because contrary to Article 19.[28]

In *Russell Jones v. Britannia Airways*[29] the Judge of the County Court ruled that the passenger rights under the provisions of the Warsaw

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[25] U.S. District Court, Southern District of New York, No.99 Civ.0585(THK), 16 February 2000: 27 *Avi* 17,596.

[26] The Warsaw Convention Article 23 (1) and Article 33.

[27] Korean Air Lines, General Conditions of Carriage for International Passenger, Article 11, Paragraph 1(1).

[28] New York Civil Court, *McMurray v. Capital Interational Airways*, 4 January 1980: 15 *Avi* 18,087.

[29] Case No. SH 714259, decision of 5 November 1998; Chester County Court, Judge Barnett ; I. H. Ph. Diederiks Verschoor, *supra* note 2, p. 302.

Convention, including Article 17 and 20, could not be limited by exclusions in the carrier's conditions of carriage (Article 23) and that the claimant was entitled to seek to prove his case under the provisions of Article 19 on the carrier's liability for damage caused by delay; the carrier would then have to prove (Article 20) that he did all he could to prevent the damage. The General Conditions of Carriage as laid down by the IATA expressly state that the times of departure and arrival do not form part of the contract of carriage. In present cases reference was made by the carrier to its own general conditions of carriage for passengers and baggage, including the 1991 edition which had similar conditions. This decision make it clear that all has to be done not only to avoid delay but also to avoid damage.[30]

In *Ets Peronny v. Ste Ethiopin Airlines*[31] the Paris Court of Appeal ruled that a clause in the air waybill stipulating that no time was fixed for the completion of the carriage, and that the carrier was authorized to select, or deviate from the route or routes of shipment, was invalid insofar as it related to cases where the performance of the air carriage took a great deal longer than the normal time and was far in excess of what the shipper could expect on the bases of his selection of that mode of transportation. Thus, the only effect produced by the provision of the Conditions of Carriage dealing with delay is to exonerate the carrier for cases of slight delay. In all cases where the delay is more than slight, the exonerating provisions of the Conditions of Carriage are not allowed to operate. The only way in which a carrier can be relieved of liability is to prove that he has taken all necessary measures to avoid the delay, or that it was impossible for him to take such measures, pursuant to Article 20(1) of the Warsaw Convention.[32]

VI. Conclusion

The Montreal Convention Article 19 provides that the carrier is liable for damage occasioned by delay in the carriage by air of passengers, baggage or cargo. However, this provision has some shortcomings as

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[30] I. H. Ph. Diederiks Verschoor, *supra* note 2, p. 302.
[31] (1975) 29 RFDA(C. A. Paris, 30 May 1975); Georgette Miller, *supra* note 7, p.155.
[32] Georgette Miller, *supra* note 7, p.155.

follows[33]: it is silent on the duration on the liability for carriage, and it does not make any distinction between persons and goods. It does not give any indication concerning the circumstances to be taken into account in cases of delay, and about the length of delay. Therefore, it is desiable to define the period of carriage with accuracy, and to insert the word 'unreasonable' in Article 19.

Although there will be no liability under Article 19 unless the delay is such that the carrier does not perform the carriage in a reasonable time, there may be liability under other provisions of the Convention. So if the delay, even if not unreasonable, causes the destruction or loss of checked baggage or cargo, there will prima facie be liability under Article 17(2) and 18(1) of the Montreal Convention.

The Montreal Convention provides the limit of liability for delay for passengers and their baggage and for cargo. The liability for delay of passengers is limited to SDR 4,150 per passenger, but the carrier has the defense of having taken all measures to avoid the delay. Baggage liability is raised to a limit of SDR 1,000 per passenger for both checked and unchecked baggage, while cargo liability is limited to an unbreakable limit of SDR 17 per kilogram.

Overbooking has become a general airline practice, and delay due to overbooking raises special problems. As overbooking is not a risk characteristic of air transport, as delay is, it should not be dealt with under the Convention, and the carrier can not rely on the terms of the Convention to limit his liability.

Where the Montreal Convention applies, any provision in the Conditions of Carriage tending to relieve the carrier of liability under the Convention is void. If the effect of the Convention is to make the carrier liable in cases of unreasonable delay, any contractual term seeking to restrict or exclude that liability can not be upheld.

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[33] I. H. ph. Diederiks Verschoor, *supra* note 2, p.301.

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DEVELOPING A "FLEET STANDARDIZATION INDEX"
FOR AIRLINE PLANNING

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Quantifying subjective aspects is a difficult task that requires a great dedication of time from researchers and analysts. Nevertheless, one of the main objectives of it is to pave the way for a better understanding of the focused aspects. Fleet standardization is one of these subjective aspects that is extremely difficult to turn into numbers. Although, it is of great importance to know the benefits that may come with a higher level of standardization for airlines, which may be economical advantages, maintenance facilitation and others. A more standardized fleet may represent lower costs of operations and maintenance plus a much better planning of routes and flights.

This study presents the first step on developing an index, herein called "Fleet Standardization Index" or FSI (or IPF in Portuguese, for "*Indice de Padronização de Frotas*"), that will allow senior airline planners to compare different fleets and also simulate some results from maintaining or renewing their fleets.

Although being a preliminary study, the results obtained may already be tested to compare different fleets (different airlines) and also analyze some possible impacts of a fleet renewal before it takes place. Therefore, the main objective of this paper is to introduce the proposed IPF index and to demonstrate that it is inversely proportional to the number of different airplane models, engines and other equipment, such as avionics.

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1   INTRODUCTION

The need for standardization of the various items, equipment and characteristics of the aircraft composing an airline's fleet is a very discussed issue among aviation specialists and also among economists involved with the aviation industry. On the other hand, few studies have been done (or publicized) on this subject, leaving the particularities of fleet standardization covered in a mist of several complex issues that are poorly explored in the conventional literature.

In view of this, the primary objective of this paper is to start a broad analytical study and stimulate further follow-on studies on airlines' fleet standardization (fleet commonality issues), while considering the factors that influence this standardization and the benefits that can be granted from a higher level of it. For this, an initial effort is made to quantify the level of standardization of a given airline fleet, bringing both study and discussion from a subjective to an objective point of view.

Due to the somewhat pioneering characteristics found in the present study, the authors acknowledge that errors may occur during the conception and development of the formulations and assumptions herein made. For this, the authors welcome any contribution, suggestion and critics made on the purpose of continuing and improving the present study, since the primary goal is to contribute directly in the analysis and understanding of the challenging, complex and dynamic world of strategic airline planning.

2   FLEET STANDARDIZATION – DEFINITIONS AND INITIAL CONSIDERATIONS

When mentioning "fleet standardization", the first common thought points to a fleet composed of the same type of aircraft (i.e. from the same manufacturer and the very same model/variant) painted in the same color scheme and aligned on the apron, just as seen in several airline ads. Through this common view, having an Embraer ERJ-145 and an Airbus A319 in the same fleet means a great loss of standardization, mainly due to the different manufacturer. Nevertheless, when going deeper into the term of "fleet standardization", one should overcome the simple view of considering basic aircraft characteristics and incorporate engines, avionics, equipment, propellers, tooling and much more in his or her analysis.

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This means that having several aircraft from different manufacturers or from a single manufacturer but of different variants may not pose a great deal, as long as these aircraft share the same engine manufacturer, for instance. As an example, four different Boeing airplanes (i.e.: 737-700, 747-400, 767-300 and 777-200) can be equipped with powerplants from a single manufacturer, even being the engines themselves different. Moreover, engines of the same family (using the same engine core) can be installed in various types of aircraft, from different manufacturers. An example is the Pratt & Whitney of Canada PT-6, used in the Cessna Caravan/Grand Caravan, the Embraer Bandeirante and the Bombardier (de Havilland) Twin Otter, just to mention a few.

In order to understand correctly the technical consideration of airline fleet standardization, we shall refer to the basics parts of an airplane.

2.1   Aircraft parts and components

When asking a child about what an airplane is, the answer would probably be somewhere near of "an airplane is a big vehicle that flies and has wings". Complementarily, aviation enthusiasts would try to better distinguish the different parts of an airplane in their response on the same question, stating that an airplane is made of wings, fuselage and engines. But for the purpose of this study we shall refer to the classification used for project and maintenance as the most appropriate means in describing an airplane, pointing that it is composed of a cell, an engine-propeller system (the powerplant), avionics and other equipment.

The cell is what we could refer as being the "hull" of the aircraft, meaning all structures, the hull itself and assorted mechanical parts. It is important to notice that in this group, we will not include any interior-related item such as seats, bins, galleys, etc. The cell alone does not fly, but it is responsible for lift forces generation.

It is very common to consider the engine-propeller group and the engine alone the same item. In fact this error occurs due to the variety of jet aircraft used nowadays, where the propeller simply does not exist or does not make itself apparent. When mentioning the "engine-propeller group", it will only make sense for turboprop or other propeller-equiped airplane, where an engine (piston or jet) is

responsible for rotating the propeller(s). The propulsion on jet aircraft is given entirely by the engine (turbojet or turbofan). For the purpose of this study, we will refer it all as "powerplant".

The avionics group is the combination of all flight, engine and navigation instruments, together with all the electronic equipment on board, essential for the various regimes of flight the airplane has been certified. In this group we can mention the ADF, VOR and GPS as examples of navigation avionics, the VHF and HF radios as communication avionics and the N_1 (or EPR) indicator as an example of engine-monitoring avionics.

Finally, the last group is the one that combines all other items and equipment of the aircraft. This group is composed of so many different items that it can be referred as "others" without incurring in a serious error. Listed in this group are seats, galleys, interior panels, tires, etc.

2.2　Aircraft cell standardization

We can consider as having the same cell all airplanes from a single *family*, such as the Boeing 737-300/400/500, the 737-NG (-600/-700/-800/-900), the Airbus A318/319/320/321, and the Embraer 135/140/145. The differences between aircraft from a same family are usually few and usually relate to their length, capacity and powerplant variants (mainly thrust). Their piloting procedures and the maintenance procedures can be considered almost the same for simplification.. However, this approach must be taken with caution: it does not mean that all Boeing 737 have the same cell, as it is widespread known that the 737-200 is quite different from the –300/400/500 family, while both are different from the –NG family. This classification of separating through *families*, takes in account the design and the aerodynamics characteristics, indeed both quite similar (if not equal) to the entire family. In the basic approach and in the simplification herein used, it is of fundamental importance knowing how to classify the aircraft in *families*, or the findings of the present study will not be valid.

It is interesting to notice that, once all aircraft from a single family are usually operated almost on the same way, the "family classification" shown above immediately implies a substantial benefit when considering crew training programs. A crew trained to operate one type of aircraft within a given family can be easily switched to operate throughout all the other aircraft of that family.

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2.3 Powerplant standardization

As mentioned before, the propeller is also a part of the engine-propeller group. On jet airplanes, we can say "engine" and "engine-propeller" indistinctly, because there is no propeller. As a follow-on to this preliminary study, a more detailed and complex analysis could consider fleets composed by all kind of aircraft (including aircraft with piston engines). In the present case, as a simplification, this paper will address the item "engines" as a whole, leaving the study of propellers' influence on standardization for the above mentioned follow-on, more detailed study. In view of this, as highlighted in the previous section, we will refer to the term "powerplant" only.

If it was possible to separate the powerplant from the cell, we could see some interesting situations. A single cell can be equipped with more than only one type of powerplant, and a single powerplant can be used with different cells, generating one or more of the following situations.

1. Same cell, same powerplant;
2. same cell, different powerplant;
3. different cells, same powerplant; and
4. different cells, different powerplant.

Low-aged fleets tend to be formed around situation #1. New entrant airlines, especially low-cost/low-fare carriers, tend to built their fleets aiming to extract the most positive results from this first situation. Middle-aged fleets, as the ones in a renewal process, can be commonly nested within situation #2. On the other hand, situation #3 is not commonly seen, but would be the case of a fleet composed by Boeings 707 and 737, that can be equipped with the same powerplant. Complementarily, situation #4 is more common on small airlines with a relatively small fleet, in particular all-cargo operators with few routes or operating cargo charter flights.

But, again, for the purpose of this preliminary study, let us concentrate solely on the powerplant. They will be classified not only in regard of its manufacturer and type, but also to the extent of what we will herein refer as variant or "dash", something like a 'sub-type'. This three-level classification is indeed complex, but it follows the same approach used for the two-level applied for the cell analysis, as will be seen on section 3.

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2.4 Avionics standardization

The study of avionics standardization is much more complex than the aforementioned cases. This is in great part due to the great variety of instruments and electronic on-board equipment. In order to picture yourself in this complex scenario, imagine being the captain or first-officer of an airline operating a Boeing 737-300 registered BR-BR1 on day-one, and having to fly the next day another 737-300 (registered, say, BR-BR2), with instruments from different manufacturers and, worse of all, with these instruments mounted on different locations on the front and overhead panels. In the extreme, this could even lead to confusing the crew on a particular switch or on/off signal during an emergency situation, posing risks of catastrophic consequences. Moreover, maintenance personnel could also encounter problems with this confusing, multiple layout flight deck configurations while in the programming procedures of daily fleet maintenance.

This type of standardization can be easier to achieve as long as the carrier blocks a given batch of airplanes coming off the production line in direct sequence. In this case, even if not clearly demanded by the carrier, there is a tendency by the aircraft manufacturer to install avionics from a same supplier on all aircraft in that batch. In fact, a good level of standardization can be achieved within a same aircraft family when the avionics are at least of the same manufacturer or the same model, which is very much possible in several isolately purchased aircraft. However, nowadays only a few airlines are able to purchase batches of aircraft directly from the manufacturer, being the leasing of diverse aircraft from international lease companies one of the most common forms of fleet composition.

Being a preliminary study, this paper will not address the complex issues of the standardization involving the avionics group and the "others" group. We encourage other follow-on studies to address in detail these and other groups not listed in this paper.

2.5 Economical aspects of fleet standardization

It should be pointed out that using equipment from the same manufacturer may lead to significant savings in maintenance, spare parts inventory, tooling, training and in buyer-supplier negotiations. The target of the negotiation shall not be achieving short-term advantages, but mid- and long-term advantages. Brazilian carriers TAM and GOL are examples of it, the first with an almost all-Airbus

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fleet (A319/320 and A330-200s, plus still a few Fokker 100s), and the second with a true all-Boeing 737NG fleet (737-700s and –800s). Although not being a target for the present paper, for a more detailed analysis of economical aspects of airline fleet standardization we recommend the approach put in discussion by Holloway (1997).

3   THE FLEET STANDARDIZATION INDEX (IPF)

Indexes (or indicators) are non-exact/non-precise tools to quantify a highly subjective aspect with no link to numerical data. Many indexes/indicators are commonly used in trying to allocate quantitative values poverty, development, customer satisfaction, and others. In spite of their existing limitations the use of indicators is continuously growing. In fact, if in one hand they are can be labeled as non-precise and non-exact, on the other hand they permit making direct and uncomplicated comparisons, which can be used, understood and discussed by almost any individual. Indexes are essential, for example, in the cost-benefit analysis, when evaluating the impact distribution of a project.

Comparing fleets is very difficult when the variety of types and models of aircraft and powerplants is such that allows almost infinite combinations between them. Moreover, discussing about fleet standardization is as difficult as comparing them. To assist in this difficult comparison task this paper introduces an index herein christened "Fleet Standardization Index", or IPF (for the initials in Portuguese of *Indice de Padronização de Frotas*).

As mentioned earlier, the formulation of the IPF is herein presented in its initial form of quantifying the level of fleet standardization. Despite this preliminary and simplistic approach, it is already possible to have a fair good idea about the status of airlines' fleets. In view of this, and considering its current preliminary format, the "Fleet Standardization Index" will be initially composed of two aspects: the standardization of airplanes' cells and powerplant. The development of the IPF formulation was made on a semi-empiric basis, starting with the following assumptions:

- The higher the number of different manufacturers of aircraft/powerplant, the lower is the level of standardization — consequently the IPF will be found proportional to the inverse of the number of manufacturers;

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- The higher the number of different models (families) of airplanes/powerplants from the same manufacturer, the lower is the level of standardization — as seen above, the IPF is proportional to the inverse of the number of different models for each manufacturer;

- The same analogy can be used for the dashes (variants, sub-types) of powerplants — this put, the IPF is proportional to the inverse of the number of powerplant variants, for each model and manufacturer.

The two aspects shown above will lead to a pair of auxiliary indexes: the "Cell Standardization Index" (or IPC, in Portuguese) and the "Powerplant Standardization Index" (or IPM, in Portuguese). In further studies, other indexes could be added in the IPF determination (i.e.: IPA for Avionics, and IPOPI for Other Parts and Items). So, the initial formula for IPF is shown below:

$$IPF = \alpha_1 \times IPC + \alpha_2 \times IPM, \text{ where } \alpha_1 + \alpha_2 = 1 \tag{1}$$

The definition of α_1 and α_2 values will be the result of practical studies and surveys, when the researcher will be able to identify and measure the influence of each type of standardization on the IPF. As a matter of simplification and in order to obtain numerical results for this preliminary study, we will assume a case where the values are 0.6 to α_1 and 0.4 to α_2. For this, expression (1) becomes:

$$IPF = 0.60 \times IPC + 0.40 \times IPM \tag{2}$$

The next and most important step is to obtain the equations for IPC and IPM. Considering the similarity between both them and again as a matter of simplification, we will address either one and then extrapolate the result to determinate the other. Later on we will mention some IPC and IPM formulas that were tried out by the authors, but were found to be non-effective.

3.1 Initial formulas

Initially, with the approach and considerations set on section 2, it was intended to pursue directly the formulation of indexes IPC (cell) and IPM (powerplant). However, a major concern arose when turning values that are proportional to the airplanes/powerplant quantities into a single expression. The intermediate solution adopted was to create partial indexes calculated for each manufacturer. These will be herein named "Cell Standardization Partial Index" (IPPC) and "Powerplant Standardization Partial Index" (IPPM, from the Portuguese abbreviations).

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3.1.1 Cell Standardization Index (IPC)

The number of airplanes from each manufacturer is used as the ponderation factor of the index, being the number of models the main quantifying factor. Due to its inverse proportionality, the IPPC expression was obtained as:

$$IPPC = \frac{total\ number\ of\ airplanes\ from\ one\ manufacturer}{number\ of\ families\ from\ that\ manufacturer \times total\ fleet} \tag{3}$$

With the IPPC in hand, tests were run in order to establish the correct formulation for the IPC. After several tests, the emerged IPC equation was:

$$IPC = \frac{\sum IPPC}{number\ of\ manufacturers} \tag{4}$$

In such a way, it was possible to ensure that the considerations seen in previous sections would be met, being the IPC inversely proportional to the number of manufacturers.

3.1.2 Powerplant Standardization Index

The same approach was used to develop the formulation for the IPM index. Nevertheless, as the powerplant considerations have a further level of detailing (different "dashes"/variants of powerplant available), an adjustment on IPPM was found to be necessary. This has emerged in another index, herein called "Model Specific Powerplant Standardization Index" (IPPMM). All expressions, for IPPMM, IPPM and IPM, are presented below.

$$IPPMM = \frac{number\ of\ powerplants\ of\ a\ model}{number\ of\ dashes\ of\ same\ model \times total\ number\ of\ powerplants} \tag{5}$$

$$IPPM = \frac{\sum IPPMM}{number\ of\ models\ from\ a\ manufacturer} \tag{6}$$

$$IPM = \frac{\sum IPPM}{number\ of\ manufacturers} \tag{7}$$

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3.1.3 Practical use of the equations developed

In order to test and present a preliminary practical use of the above listed formulas, a sample airline "Air Studies" will be considered. This airline operates a fleet of aircraft from three different manufacturers, ALFA, BRAVO and CHARLIE, as listed on Table 1. The sample powerplants are listed in the right column of Table 1 and also on Table 2, on the sequence.

Table 1: Fleet operated by sample airline AIR STUDIES

Maker	Model	Qty.	Type	Powerplant
ALFA	ALFA-100	4	Twin jet	W-1-2
		3	Twin Jet	W-1-3
	ALFA-200	9	Twin Jet	W-7-2
BRAVO	B-1	2	Twin Jet	W-1-2
		8	Twin Jet	Y-90-F
	B-2	12	Twin Jet	Y-100-A
		25	Twin Jet	Y-100-B
	B-3	8	Twin Jet	Y-2000-Z
CHARLIE	CH-10	12	Twin Jet	Y-100-C

Table 2: Powerplant combinations used on sample airline AIR STUDIES airplanes

Manufacturer	Model	No. of variants/dashes	Total qty.
WALKER MOTORS	W-1	2	9 x 2 = 18
	W-7	1	9 x 2 = 18
YIELD AVIATION ENGINES	Y-90	1	8 x 2 = 16
	Y-100	3	37 x 2 = 74
	Y-2000	1	2 x 2 = 04

Calculating the IPC (Cell Standardization Index) for carrier Air Studies:

♦ Manufacturer ALFA: 2 different cell models, 16 airplanes total:

$$IPPC = \frac{16}{2 \times 83} = 0.096 \qquad (8)$$

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- Manufacturer BRAVO: 3 different cell models, 55 airplanes total

$$IPPC = \frac{55}{3 \times 83} = 0.221 \tag{9}$$

- Manufacturer CHARLIE: 1 cell model, 12 airplanes total

$$IPPC = \frac{12}{1 \times 83} = 0.145 \tag{10}$$

- The IPC for Air Studies is:

$$IPC = \frac{0.096 + 0.221 + 0.145}{3} = 0.154 \tag{11}$$

The next step, using Table 2 data, is to obtain the IPM for our virtual Air Studies carrier. Together with the calculated IPC, it will compose the IPF as shown in formula (2).

- Manufacturer Walker: 18 W-1 engines of 2 "dashes" and 18 W-7 engines of a single "dash".

$$IPPMM_{W-1} = \frac{18}{2 \times 166}; \; IPPMM_{W-7} = \frac{18}{1 \times 166}; IPPM_{WALKER} = \frac{0.163}{2} = 0.082 \tag{12}$$

- Manufacturer YIELD: 16 Y-90 engines of a single type, 98 Y-100 engines of 3 types and 16 Y-2000 engines of a single type.

$$IPPMM_{Y-90} = \frac{16}{1 \times 166}; \; IPPMM_{Y-100} = \frac{98}{3 \times 166};$$
$$IPPMM_{Y-2000} = \frac{16}{1 \times 166}; IPPM_{YIELD} = \frac{0.389}{3} = 0.130 \tag{13}$$

- Follows the IPM for Air Studies:

$$IPM = \frac{\sum IPPM}{\text{number of manufacturers}} = \frac{0.212}{2} = 0.106 \tag{14}$$

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♦ Finally, the IPF is obtained with formula (2):

$$IPF = 0.60 \times 0.154 + 0.40 \times 0.106 = 0.135 \tag{15}$$

It is important to observe that the result, alone, is of no meaning. However, when advancing to the next step of comparing the indexes for different airlines it would be possible to notice which carrier has a higher or lower level of standardization. Moreover, it can be used as a strategic tool in assisting and analyzing opportunities for fleet renewal.

3.2 Rejected formulas

In this section we will present some of the rejected formulas. Those herein listed were discarded because the results obtained were found to be incorrect and/or inconsistent in some particular situations. However, they were extremely valuable in the development of the initial formulas presented in section 3.1. As a matter of simplification, the formulas below will only be presented with its main discarding reason. Its development will not be presented.

3.2.1 First rejected formula

The following formula was the first to be rejected during the development of the indexes.

$$IPC = \sum IPPC \tag{16}$$

The reason for discarding formula (16) was the fact that the IPC (or IPM) would increase if the number of manufacturers had also increased. When analyzing the cell (or the powerplant) individually, having aircraft from more than one manufacturer, clearly the fleet will be less standardized, thus directly conflicting with what would be set in formula (16).

3.2.2 Second rejected formula

The tests following the previous rejection paved the way to discarding the equation shown below.

$$IPM = 1 - \sum IPPM \tag{17}$$

This formula solved the initial problem found with formula (16), but another problem of the same sort was then created. At that point the IPM (or IPC) increased with the increase in the number of

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models, what would be also incorrect. The next step taken to re-analyze and run other tests came to solve this problem, leading to the correct formulas, presented in the previous sections.

3.3 General considerations for future development

As highlighted previously, the present approach does have limitations, the primary being that it does not yet consider the avionics and the "others" groups, both extremely relevant for a strategic fleet planning in the real complex world of airline planning. However, these limitations can be minimized with further analysis and research. The limitations identified during our study and some possible solutions are presented and discussed below.

The first drawback of the present preliminary development phase is the low capability of the IPF index in allowing planners not only to compare different fleets or situations but also its low capability in presenting them the correct feeling of quantity. In other words, a simple verification of the IPF value should be sufficient to understand the degree of standardization of that particular airline, which is still not the case with the equations herein depicted. In fact, the IPF index developed herein is sufficient only to conduct comparisons between different airlines (different fleets).

A more in depth mathematical approach, with the analysis of sample cases in a crescent or decreasing standardization sequence, could lead to a robust solution in helping correct the above mentioned drawback. Meanwhile, it is the understanding of the authors that the basis for calculation of IPF and related indexes and sub-indexes could be kept unchanged. The central point could be the linearization of results, and the task is to find a mathematical method to perform it. The authors have not yet used exponential factors, but it is believed that it could be a good way to achieve the desired results. Follow-on studies are being planned in this direction.

Another important limitation that do deserve attention is the numerical compatibility between IPC and IPM. At the present moment the values obtained for both seem to be incompatible in terms of dimensions, while the ponderation (weight) system used has been arbitrary. The follow-on study, now in its initial phase ("phase 2" of the entire original research project), is also being aimed at the necessity of the final IPF be obtained from comparable and compatible IPC and IPM values, to be

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sure that the influence of cell and powerplant standardization are correctly balanced and accounted for. A reasonable form to pursue is to adequate $á_1$ and $á_2$ values in formula (1), thus pointing to a change in expression (2). Nevertheless, the basis for IPF calculation will still remain the same, as the results herein exposed remain valid for comparison purposes.

It is the understanding of the authors that a complex mathematical effort shall be employed to develop the final formula, which would then minimize to the maximum the limitations discussed and presented in the previous lines. This quantitative effort may include the measurement of influences and the linearization of both IPC and IPM.

The authors encourage other researchers to collaborate in this effort, even if departuring from the original approach taken by the present study.

4   CONCLUSIONS AND CONSIDERATIONS

The Fleet Standardization Index (IPF), as presented in this pilot study, allows the quantification of a highly subjective aspect: the level of standardization between airline fleets. The comparison between two or more different fleets, from different airlines or simulating changes in an actual airline, can be made with the IPF.

However, some drawbacks have been identified by the authors in the formulation of the IPF itself and its components IPC (for the cell) and IPM (for the powerplant). Although limiting its effectiveness as a sole index (when not used to comparing different fleets or carriers), the problems identified can be minimized to a great extend. Follow-on studies to this research herein presented are already being drafted in order to realign the formulations. When this is achieved, it will permit the usage of the IPF index alone, without the need for comparison between different fleets and/or carriers (as the current model dictates).

For this, the authors endorse their encouraging towards other researchers to analyze and consider in more detail the multiple influential aspects of airline fleet standardization in order to verify the level of influence of each factor in the final airline IPF.

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