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Editors
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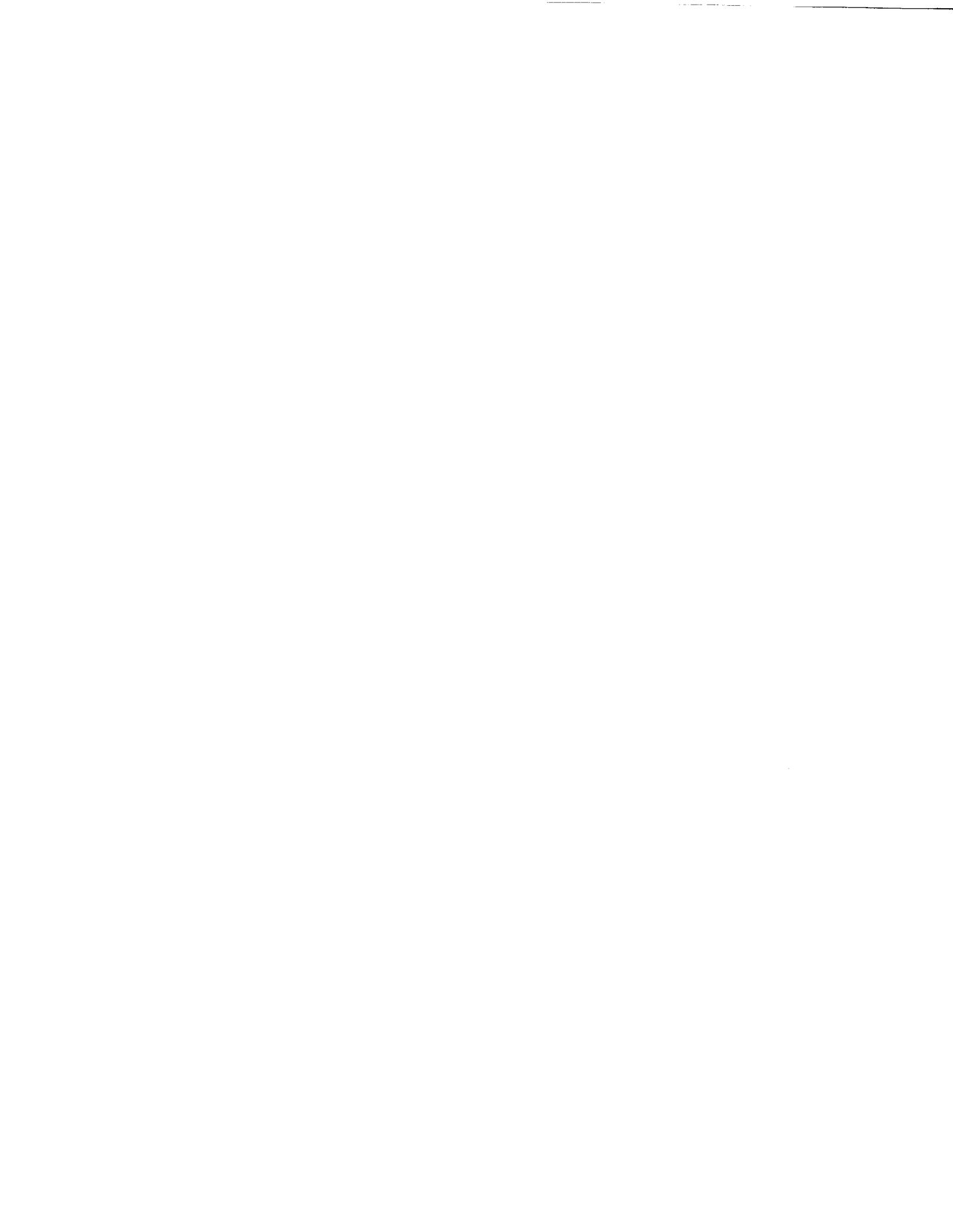
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## ABOUT THE EDITORS

Dr. Tae H. Oum is Van Dusen Foundation Professor of Management, Faculty of Commerce and Business Administration, the University of British Columbia, Vancouver, Canada. Dr. Oum specializes in policy analysis, demand modeling, cost and productivity analysis, and analysis, demand modeling, cost and productivity analysis, and globalization and competitiveness issues affecting the transportation and telecommunications industries. He has published and edited over 20 books and numerous papers in international journals and regularly advises Canadian and foreign government agencies, major corporations, and the World Bank on transportation and telecommunications policy and management issues. In particular, he has recently published a major book "WINNING AIRLINES: Productivity and Cost Competitiveness of the World's Major Airlines" (Kluwer Academic Publishers, 1997). Dr. Oum is the President of the Air Transport Research Group (ARTG) and Chair of the Publication Committee of the World Conference on Transport Research (WCTR) Society. He also serves on the editorial boards of the Journal of Transport Economics and Policy, Transport Policy, Journal of Air Transport Management, Transportation Research Series E, and Journal of Air Transportation World Wide. Dr. Oum is the Canadian Advisor for the Transportation Task Force of the Pacific Economic Cooperation Council (PECC).

Dr. Brent D. Bowen is Director and Professor, Aviation Institute, University of Nebraska at Omaha. He has been appointed as a Graduate Faculty of the University of Nebraska System-wide Graduate College. Bowen attained his Doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor, Advanced-Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment in collegiate aviation programs. He is also well published in areas related to effective teaching. His professional affiliations include the University Aviation Association, Council on Aviation Accreditation, World Aerospace Education Organization, International Air Transportation Research Group, Aerospace Education Association, Alpha Eta Rho International Aviation Fraternity, and the Nebraska Academy of Sciences. He also serves as program director and principal investigator of the National Aeronautics and Space Administration funded Nebraska Space Grant and EPSCoR Programs.

## *ATRG President's Foreword*

The **Air Transport Research Group** of the WCTR Society was formally launched as a special interest group at the 7th Triennial WCTR in Sydney, Australia in 1995. Since then, our membership base has expanded rapidly, and now includes over 400 active transportation researchers, policy- makers, industry executives, major corporations and research institutes from 28 countries. Our broad membership base and its strong enthusiasm have pushed the group forward, to continuously initiate new events and projects that benefit the aviation industry and research communities worldwide.

It became a tradition that the ATRG would hold an international conference at least once a year. As you know, the 1997 conference was held in Vancouver, Canada. Over 90 papers, panel discussions and invited speeches were presented. In 1998, the ATRG organized a consecutive stream of 14 aviation sessions at the 8th Triennial WCTR Conference (July 12-17: Antwerp). Again, on 19-21 July, 1998, the ATRG Symposium was organized and executed every successfully by Dr. Aisling Reynolds-Feighan of the University College of Dublin.

As in the past, the Aviation Institute at the University of Nebraska at Omaha (Dr. Brent Bowen, Director of the Institute) has kindly agreed to publish the Proceedings of the 1998 ATRG Dublin Symposium (being co-edited by Dr. Aisling Reynolds-Feighan and Professor Brent Bowen), and the Proceedings of the 1998 WCTR-ATRG Conference (being co-edited by Professors Tae H. Oum and Brent Bowen). On behalf of the ATRG members, I would like to express my sincere appreciation to Professor Brent Bowen and to the staff at the Aviation Institute of UNO for their efforts in publishing these ATRG proceedings. Also, I would like to thank and congratulate all the authors of the papers, for their fine contribution to the conferences and the Proceedings.

Finally, I would like to draw your attention to the ATRG newsletter and the ATRG website (www.commerce.ubc.ca/atrg/) which will keep you informed of the ATRG operations and forthcoming events. On behalf of the ATRG Networking Committee, I would also appreciate it very much if you would encourage others in the field, to sign up for ATRG membership. Thank you for your attention.

**Tae H. Oum**
**President, ATRG**

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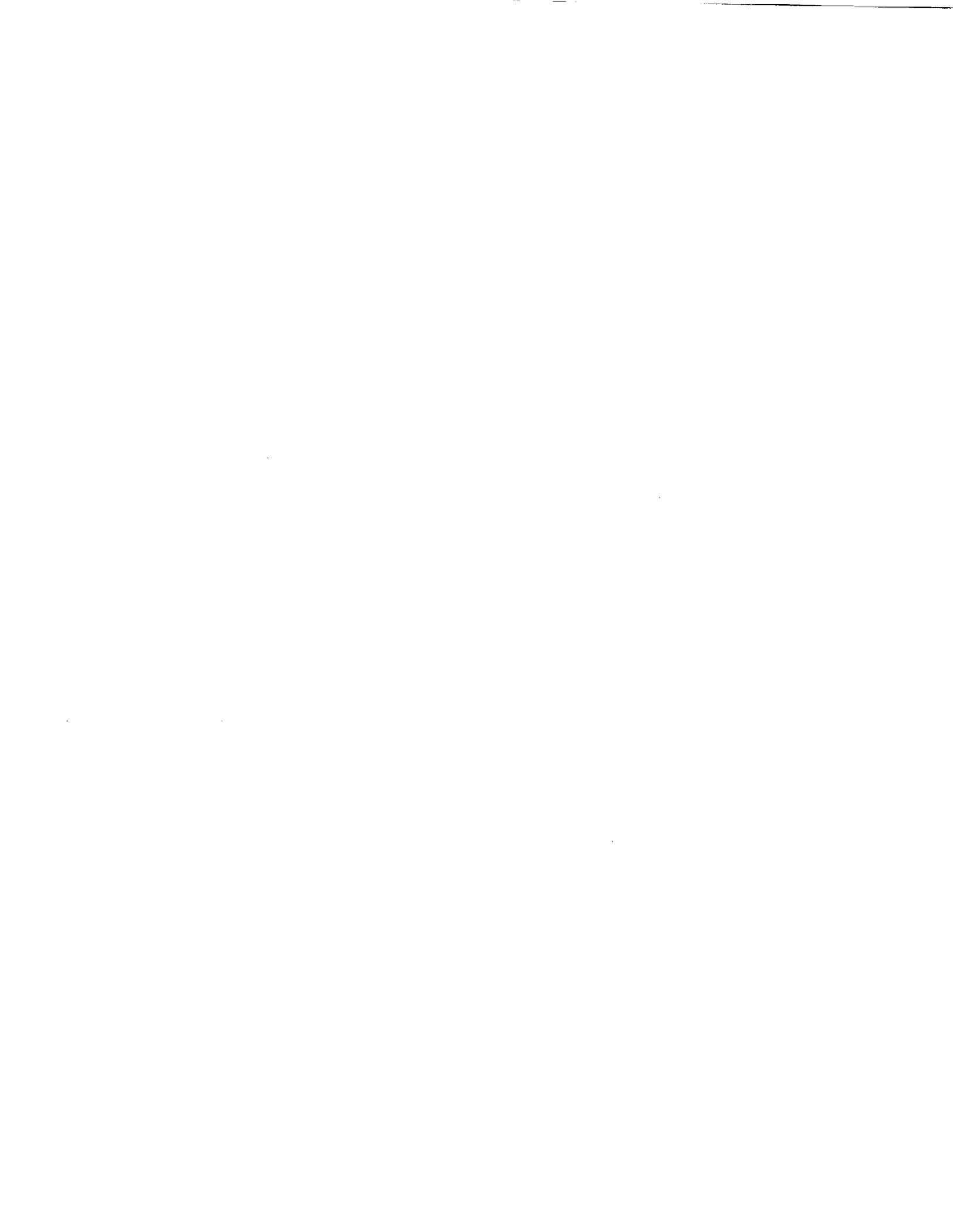
The ATRG held its Conference at the 8th Triennial World Conference on Transportation Research in Antwerp, Belgium in July 1998.

The 1998 Conference contained 14 aviation and airport sessions. Over 60 research presentations were featured on the topic, Airports & Aviation; these titles are listed on the ATRG website (http://www.commerce.ubc.ca/atrg/).

## The Proceedings

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# Airport choice in a multiple airport region: an empirical analysis for the San Francisco Bay Area.

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## Abstract

In this paper a nested logit model is used to describe passenger preferences concerning airports and airlines. A statistical model for the passengers' sequential choice of airport and airline is calibrated. It appears that the choice sequence first airport, then airline is statistically preferable to the reversed choice sequence. Frequency, the average number of seats offered by an airline and access time to the airport are all significant. Separate models are estimated for business and leisure travelers, but there appear to be only small differences.

**KEYWORDS:** airport and airline choice, nested logit models.

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# 1    INTRODUCTION

Airports are nodal centers in an air transport network. They are a sine qua non for the aviation sector. But the size and configuration of mutually linked airports is a complicated research issue which deserves due attention, as the structure and development of airports is decisively influenced by both market forces and regulatory regimes. In a deregulated air transport market, airports have to justify their existence by attracting and accommodating enough passengers to, at least, break even. In a multiple airport region, airports will compete for origin (destination) passengers. Moreover, airports may compete with other (not necessarily close-by) airports for transfer passengers. In a previous paper (Pels et al., 1997), it was found -on the basis of a theoretical model- that airport pricing policies do not influence the airline's network choice as much as the level of demand. This result needs of course further empirical underpinning and testing.

In this paper we address the question which variables influence the level of demand in a multiple airport region and how airports can use these insights in their efforts to attract more passengers. In a multiple airport region, passengers have to decide both which airport and which airline to use. Competition between (origin) airports for passengers cannot be analyzed without taking into account the airlines' reactions to the airports' policies; see e.g. Pels et al. (1998). Consumer choices are thus critical in this context, and, therefore, we will analyze passenger preferences concerning airports in relation to their preferences concerning airlines. The nested logit model is an appropriate tool for this analysis. The logit model is widely used in the literature on airport (and airline) choice; hence we can compare our findings to previous findings using similar models. Moreover, on the basis of a nested logit demand function it is possible to develop a competition model in which airlines compete on the basis of both fares and frequencies and airports compete on the bases of airport taxes (see Pels et al., 1998).

Seen from this perspective, the purpose of the present paper is to determine: (i) which variables are the most important (significant) determinants of the passengers' airport choice, (ii) the preferred specification of the statistical model and; (iii) how these results (and the statistically preferred model) can be used to analyze airport competition in a multi-airport context.

The paper is organized as follows. In Section 2 a concise review of the literature on passenger preferences concerning airports and airport choice is given. Next, Section 3 presents the econometric model. Section 4 presents a description of the data used and the estimation results. Section 5 offers some conclusions.

## 2    LITERATURE REVIEW ON DICSCRETE CHOICE MODELS

As mentioned above, passengers (or an agent on their behalf) have to decide on both the preferred airport and the preferred airline. These choices can be based on frequency of service, the airfare (the airlines' policy variables) and airport tax and accessibility (airport policy variables and characteristics). A common method to model these choices is the multinomial logit model (MNL), which is easy to apply and has clear interpretations. All subsequent references in this section use the MNL.

Ashford and Benchemam (1987) model the passengers' choice of airport in central England in the period 1975-1978. Travel time to the airport, fare and frequency of service were taken as the explanatory variables. It was found that for business travelers, travel time was the dominant determinant of airport choice; the frequency of service was the second most important variable. Fare was found to be the dominant factor for leisure and domestic travelers. Thompson and Caves (1993) model the passengers' choice of airport in the North of England in 1983. For leisure travelers, the access time to the airport, the airfare and the maximum number of seats available were found to be significant variables for the airport choice. For business travelers, the access time, frequency of service and the number of seats were found to be significant. However, in the "business model", the seats variable had a negative sign while the authors expected a positive sign (which was found in the "leisure model"). Caves et al. (1991) analyze the passengers' choice between selected British airports and identify access time, frequency, and fare as significant variables. Moreover, they conclude that "the hypothesis that frequency is an airport specific variable when considering the competition between an emerging and a mature airport cannot be rejected".

Hansen (1990) estimates market shares of airlines in origin-destination markets. The estimated market share is then used as input for an airline competition model. For direct services, the explanatory variables are the airfare and the (log of) frequency of service. For connecting services, explanatory variables are airfare, frequency of service

on the minimum and maximum frequency link and the circuity of service (as a measure of the extra distance associated with the indirect connection). All variables are significant. Harvey (1987) concludes that an MNL with access time and frequency of service as explanatory variables provided a good approximation of airport choice in the San Francisco Bay Area. Both access time and frequency of service are included in a non-linear fashion to capture the diminishing marginal utility (disutility) of frequency (access time). Fares are omitted in the analysis, because (i) no information is available on the fare actually paid by each separate traveler and (ii) there appears to be more variation among fare classes on a given flight to a particular destination than among different flights to that destination or airport.

The MNL is indifferent between any similarity or dissimilarity between alternatives; all are treated as equal. If an new alternative is added to the choice set, it will gain its share by a proportional reduction of the shares of the existing alternatives. If a new airline starts operations from a single airport out of a multiple airport region, under a MNL specification *all* other airlines in the region will suffer a proportional reduction of their market share; the fact that airlines may operate out of different airports and as a consequence some airlines may suffer more than others is neglected. This IIA (independence of irrelevant alternatives) property may lead to unacceptable results. The nested multinomial logit model (NMNL) does away with the IIA property by identifying groups of alternatives. Ndoh et al. (1990), using UK data, find that a nested multinomial logit model is statistically preferred to an MNL. Bondzio (1996) analyzes the passengers' choice of airport and access mode, and finds that for business travelers an NMNL (with access mode as nest) and for leisure travelers MNL models are the most preferred.

Based on this concise review, we may conclude that an MNL is frequently used in the literature to describe passengers' airport or route choices. Variables of influence appear to be travel time (to the airport), frequency and airfare. It may be, however, that a NMNL is to be statistically preferred.


## 3    A MODEL FOR THE JOINT AIRPORT-AIRLINE CHOICE

In this section the discrete choice model is formulated for the joint airport-airline choice.

A passenger flies with an airline from an airport in a multiple airport region to a given destination. The traveler then has to make two choices; one for the origin airport and one for the airline. These choices are based on the (maximum) (in)direct utility the passenger derives from using a particular (combination of) departure airport $d$ and airline $l$.

We distinguish between aggregate alternatives (airlines) and elemental alternatives (seats). In a market between an origin airport and a particular destination, an alternative "airline $l$" consists of a number of flights on that route; call this number $f_l$ for frequency. With an average number of seats per flight $s_l$, the "size" of airline $l$ in this particular market is $S_l = f_l s_l$: airline $l$ offers $S_l$ elemental alternatives (seats). A passenger derives a utility $U_{l,j} = V_{l,j} + \varepsilon_{l,j}$ ; $j=1,\ldots,S_l$ from each of the elemental alternatives. The average systematic utility of an elemental alternative is $\overline{V}_l = \frac{1}{S_l}\sum_j V_{l,j}$.

If the utilities of all elemental alternatives $j$ are IID (which implies $\overline{V}_l = V_{l,j}$, $\forall j$; the utility of a seat equals the average utility over all seats), it can be shown that the distribution of the utility of the aggregate alternative $l$ approaches the Gumbel distribution[i] with a location parameter $\eta = \overline{V}_l + \alpha \ln(S_l)$. The total utility derived from airline $l$ can then be written as $U_l = \overline{V}_l + \alpha \ln(S_l) + \varepsilon_l = \overline{V}_l + \alpha \ln(f_l) + \alpha \ln(s_l) + \varepsilon_l$ (see Ben-Akiva and Lerman, 1987, chapter 9). Note that both $f_l$ and $s_l$ have the same parameter $\alpha$; this is a scale parameter of the Gumbel distribution of $U_l$.

The average systematic utility of alternative "airline $l$", $\overline{V}_l$, is determined by the airfare $p_l$ and aircraft or flight characteristics, such as the level of comfort and the flight time. Aircraft size can be seen as an indicator of the level of comfort; larger aircraft are more commonly used on long distance routes and have more amenities. Using the average number of seats as a proxy for aircraft size and including it in logarithmic form, multiplied by a parameter $\beta$, in the utility function to account for decreasing marginal utility (disutility) of comfort (travel time), the systematic utility derived form airline $l$ is

$$\begin{aligned} V_l &= \alpha_l + \alpha_p p_l + \alpha \ln(f_l) + (\alpha + \beta)\ln(s_l) \\ &= \alpha_l + \alpha_p p_l + \alpha_f \ln(f_l) + \alpha_s \ln(s_l) \end{aligned}$$

(1)

where $p_l$ is the airfare charged by airline $l$; $\alpha = \alpha_f > 0$, $\alpha_p < 0$. $\alpha_s = \alpha + \beta$ is assumed to be positive; at a given stage length we assume passengers prefer larger aircraft. The utility of using airport $d$ depends on the access time to the airport $t_d$ ($\beta_t < 0$):

$$V_d = \beta_d + \beta_t t_d \tag{2}$$

The airport and airline choices can be made sequentially or simultaneously. In Figure 1 two nested structures for the sequential choice are presented.

*Figure 1 about here*

In Figure 1a we assume the passenger first chooses an airport and then an airline. In Figure 1b the choice sequence is reversed. The probability that a combination (departure airport $d$, airline $l$) is chosen can be expressed as:

$$P(l,d) = P(l|d)P(d) \tag{3}$$
$$P(l,d) = P(d|l)P(l) \tag{3'}$$

where equation (3) corresponds with the choice structure presented in Figure 1a, while equation (3') corresponds with Figure 1b. The conditional and marginal probabilities in equation (3) are:

$$P(l|d) = \frac{\exp(\frac{V_l}{\mu})}{\sum_{l'} \exp(\frac{V_{l'}}{\mu})} \tag{4}$$

$$P(d) = \frac{\exp(V_d + \mu \ln \sum_l \exp\left(\frac{V_l}{\mu}\right))}{\sum_{d'} \exp(V_{d'} + \mu \ln \sum_l \exp\left(\frac{V_l}{\mu}\right))} \tag{5}$$

The parameter $\mu$ represents the degree of heterogeneity of airlines (flights) operating from an airport. The closer $\mu$ is to 0, the higher the degree of substitutability between airlines, with $0 < \mu \leq 1$[ii]. For $\mu = 1$ the NMNL reduces to the MNL.

Adjustment of equations (4) and (5) to fit equation (3') rather than equation (3) is straightforward. In the following section both specifications will be tested against the MNL.

# 4    APPLICATION TO THE SAN FRANCISCO BAY AREA

In this section the model of section 3 will be estimated using data for the San Francisco Bay Area. The estimation results will be presented in Subsection 4.2; first however, in Subsection 4.1, some general characteristics of the data set will be presented.

## 4.1    The 1995 MTC Airline Passenger Survey

Passenger characteristic data used in this analysis were obtained from the 1995 Airline Passenger Survey conducted by the Metropolitan Transportation Commission (MTC), Oakland, CA. The survey was held in two waves, from August 25 to August 31 and from October 19 to October 27 1995, for the San Francisco (SFO), Oakland (OAK) and San Jose (SJC) airports. At Sonoma County Airport (STS) the survey was held on September 6 and 7 and October 31. In Table 1 the number of (accurate) responses along with the total number of enplanements at each airport in 1995 is given. The relatively (too) large number of interviews at SJC was conducted at the request of the airport authority (MTC, 1995). We account for this in the estimation procedure; see subsection 4.2. A vital variable in the analysis is the access time to the airport. The access time is calculated on the basis of the latitude and longitude of the location the passenger left from and the airports. Using geo-spatial data on the Bay Area road system available from the Bureau of Transport Statistics[iii], access times can be calculated.

*Table 1 about here*

In Table 2 the percentage of travelers according to destination is given. It is clear that the North American market (US and Canada) is by far the largest market. SFO and

STS have some international traffic, while at SJC and OAK international traffic is marginal.

*Table 2 about here*

In Table 3 the trip purpose is given for the respondents at each airport. At STS the majority of respondents is on a business trip. Also at SJC the majority of travelers is on a business trip, though the difference between the number of leisure travelers and business travelers is less pronounced. At the two other airports leisure travelers form the largest group.

*Table 3 about here*

Information on frequencies and average numbers of seats offered by airlines were obtained from OAG Market Analysis, OAG World Wide. Data on fares was only available for flights originating from SFO.

## 4.2    ESTIMATION RESULTS

In this subsection the estimation results of the joint airport-airline choice model are presented. The purpose is to test the specification in equation (3) against the specification in (3') and the MNL-specification. To be able to estimate airport choice models, only those respondents were selected that had two or more airports to choose from; based on the stated destination, choice sets could be defined for each passenger. The Bay Area choice sets for October (for the nested specifications (3) and (3')) are depicted in Figure 2[iv].

*Figure 2 about here*

Note in Figure 2a there is one degenerate case (within the "nest" STS there is only one possible alternative), while in Figure 2b there are more degenerate cases. In the empirical exercise, separate models are estimated for business and non-business travelers.

The utility functions are specified in equations (1) and (2)[v]. As already mentioned in subsection 4.1, a disproportionally large number of interviews was conducted at SJC. Moreover, as passengers were interviewed just before they boarded their flight (i.e. actual choices were sampled), there is the problem of endogenous

stratification. To accommodate for these problems, weighted estimations have been carried out (see e.g. Maddala, 1983). To calculate the weights we need the sample fractions and population fractions for each alternative (airport-airline combination). The latter are unavailable. However, from Table 1 we can determine the airports' population fractions, $\rho_d$, for 1995. At each airport, we can determine the relative size $\sigma_{i,d} = S_i / \sum_{i'} S_{i'}$ of each airline operating from that airport. Then the population share for each alternative is approximated as $\rho_d \sigma_{i,d}$.

Results for the business travelers are reported in Table 4. For business travelers, the nested structures with the choice sequence first airline, then airport were rejected as in all cases $\alpha_s$ was smaller than 0 (and in most cases $|\alpha_s| > \alpha_f$, which is unlikely, see section 3). Separate models for August and October were estimated. In August a model with airport specific constants is the preferred model, while in October the model without airport specific constants is preferred (the model with airport specific constants is rejected because the inclusive value parameters are larger than 1, see Section 3). In all the estimations the parameter $\mu$ is made airport specific; the parameter representing the heterogeneity between airlines operating from the *same* airport is not necessarily the same over all airports. Reestimating the model with the airport specific constants fixed at 0 we reproduce the model without airport specific constants. The LR-test of the model with the constants fixed at 0 against the model with "free" airport specific constants is 8.226; hence the hypothesis that the airport specific constants can are all 0 is not rejected at the 95% confidence level. When all $\mu$'s are 1 the nested model reduces to the MNL. Fixing the $\mu$'s at 1 and performing a likelihood ratio test we can test the nested structure against the MNL structure[vi]. This is reported in Table 4. In all cases the hypothesis that the MNL is a restricted version of the NMNL is rejected. This implies clusters of (similar) airport-airline alternatives do exist (the IIA property is rejected). We conclude that for the business travelers a nested model with the airports as nests and without airport specific constants best explains the joint airport-airline choice. Given the substantial differences between the August- and October estimates, separate estimates are preferred as these reflect seasonal influences.

*Table 4 about here*

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Based on the parameter estimates presented in Table 4, elasticities of demand can be computed. These are reported in Table 5 (see Appendix 1 for details). From Table 5 it appears that demand at STS (a small airport with only 1 airline available in the choice set) is relatively insensitive compared to the other three airports. The elasticities of frequency (and seats) are smaller than 1 at SFO (and SJC) and higher than 1 at OAK; a 1 percent change in the frequency will make OAK relatively more attractive than SFO. Pels et al. (1998) argued that a necessary condition for an airfare-frequency equilibrium to exist in a multiple airport region is that the frequency elasticity of demand is smaller than 1. This is the case for the Bay Area. At SFO, SJC and OAK, a 1 percent change in the number of available seats will result in a more than 1 percent change in demand (as the "size" of the airport in terms of available seats and the quality have increased). A 1 percent change in the access time will lead to a less than 1 percent change in demand. The access time elasticity is negative and in almost all cases smaller than 1 in absolute value. Note the (in absolute value) very high elasticity at OAK in August. Compared to the other elasticities this finding seems rather awkward. It could be a statistical phenomenon or could be due to a exogenous shock (e.g. an infrasturcture project) which had a temporal effect on OAK's accessibility.

*Table 5 about here*

Estimation results for leisure travelers are presented in Table 6. The choice sequence is first airport, then airline. The preferred model for August is the model with airport specific constants $\beta_a$, while for October the model without the airport specific constants is preferred. Again, airport specific $\mu$'s are estimated. For the reversed choice sequence the seats parameter was negative and in absolute value larger than the frequency parameter. Therefore the reversed choice sequence (first airline, then airport) was rejected. Again, the MNL specification (and with it the IIA property) is rejected. It appears parameter estimates vary more over time than over passenger types. Based on the literature review we would expect more pronounced differences between passenger types. It should however also be noted that the airfare was not included in the analysis. Various authors have found the airfare to be of influence on both the airport- and route choice; see Section 2.

*Table 6 about here*

Based on the parameter estimates presented in Table 6, we can calculate the elasticities presented in Table 7. In most cases, the frequency elasticities appear to be smaller and the access time elasticities appear to be larger for leisure travelers; the difference is more pronounced with the access time elasticities. Note again the high access time elasticity at OAK in August.

Ashford and Benchemam (1987), using UK data, found both access time and frequency elasticities were higher for business passengers than for leisure travelers. Moreover, for business travelers access time elasticities were higher than frequency elasticities, opposite to our findings presented in Table 5. Caves et al. (1991) found frequency elasticities for business passengers in the UK of about 0.11-0.18. These are significantly smaller than the elasticities presented in Table 5. These differences may be attributed to (i) the different model specification, (ii) the different geographical location and (iii) the different time period. Further research should indicate what is the main cause of the difference. Harvey (1987), using Bay Area data for 1980, included both the relative direct flight frequency and a quadratic frequency term; these parameter estimates are difficult to compare with those in Table 5. Hansen (1990) finally used the log of (direct) frequency as an explanatory variable in a route choice model. The estimated coefficient of 1.29 is not far removed from the estimations presented in Tables 5 and 7.

*Table 7 about here*

In Tables 4 and 6 no airfare parameters are presented because the necessary data are not available. Only for a limited number of flights originating from the city of San Francisco standard airfares are available. It was not possible to derive any meaningful airfare parameters based on these limited choice sets. However, based on the estimations presented in Tables 4 and 6 and the (not-presented) estimations including the airfares, we do conclude that the parameter estimates presented in Tables 4 and 6 are rather robust.

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# 5    CONCLUSION

In this paper a statistical model for the passengers' sequential choice of airport and airline was formulated. Based on theoretical arguments, the frequency of service was included in logarithmic form. The main finding is that both business and leisure travelers choose the departure airport and airline sequentially (first airport, then airline). The IIA therefore is rejected; the basic alternatives (airport-airline combinations) cannot be treated as equal. Clusters of alternatives exist, and are defined by the airport from which the airlines operate. This also has implications for a competition model. An airline faces two types of competitors: competitors operating from the same airport and competitors operating from other airports. Seen like this, airlines operating from the same airport may have conflicting interests (all try to get the largest market share possible). But opposed to the airlines operating from other airports, they may have the same interests (an increase of the airports market share, which they will then divide amongst themselves). The same holds true for the interaction between airports and airlines. Although they both may benefit from an increased demand at the airport, they may also have conflicting interests (e.g. an airline cashes in on the increased attractiveness of the airport at the expense of the airport, see Pels at al., 1998).

In general, the estimations presented compare to those found in the literature. There are, however, two notable distinctions. First, there are little differences between the estimations for business and leisure passengers. A more common result is that leisure travelers are more sensitive to cost and business travelers are more sensitive to schedule convenience. Second, passengers choose first the departure airport and then the airline, rather then choosing both simultaneously.

# ACKNOWLEDGMENTS

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# Appendix 1    Derivatives

At the individual level, the elasticity of logit is:

$$\varepsilon_{i,x_i}^{P_i(l,d)} = \frac{\partial \ln\left(P_i(l,d)\right)}{\partial \ln(x_i)} = \frac{\partial \ln\left(P_i(l|d)\right)}{\partial \ln(x_i)} + \frac{\partial \ln\left(P_i(d)\right)}{\partial \ln(x_i)} =$$

$$\left(1 - P_i(l|d)\right)\frac{\beta_x x_i}{\mu} + P_i(l|d)\left(1 - P_i(d)\right)\beta_{ix} x_i$$

where the subscript $i$ denotes the traveler. When $x_i$ appears in logarithmic form in the utility function, $\varepsilon_{i,x_i}^{P_i(l,d)}$ is multiplied by $\dfrac{1}{x_i}$.

The aggregate elasticity is

$$\varepsilon_x^{\overline{P(l,d)}} = \frac{\sum_i P_i(l,d)\varepsilon_{i,x_i}^{P_i(l,d)}}{\sum_i P_i(l,d)}$$

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*Figure 1*     *Nested Choice Structures*

Figure 1a, Choice sequence: first airport, then airline
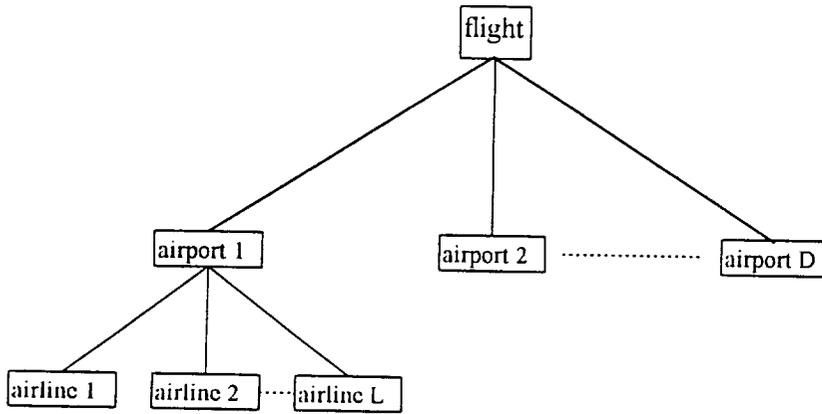


Figure 1b, choice sequence: first airline, the airport
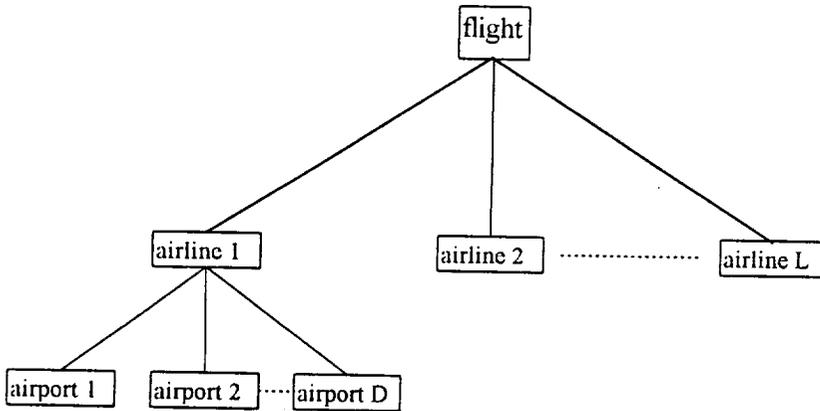
*Figure 2 Nested Structures for the airport-airline choice*[a,b]

Figure 1a: Choice sequence: first airport, then airline
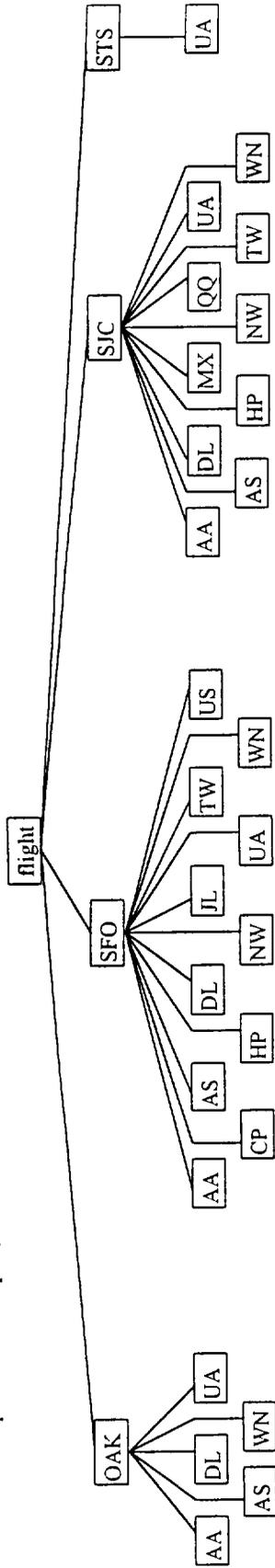
Figure 1b Choice sequence: first airline, then airport
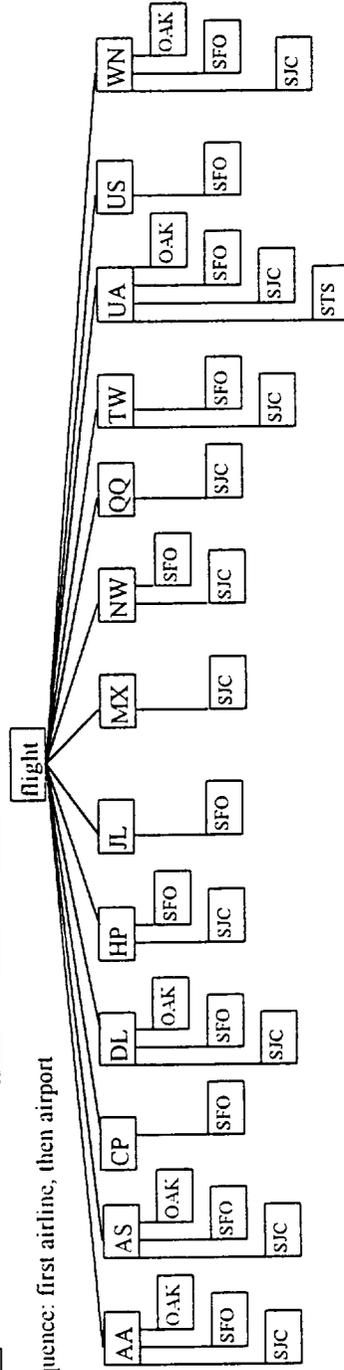
a) These are the full choice sets. Not all alternatives may be available to an individual; the actual alternatives available depend on the destination. The destinations are: Boston MA), Chicago (IL), Dallas-Ft. Worth (TX), Philadelphia (PA), Denver (CO), Boise (ID), Las Vegas (NV), Reno (NV), Salt Lake City (UT), Buffalo (NY), Los Angeles (CA), Ontrio (CA), San Diego (CA), Santa Barbara (CA), San Francisco (CA), Orange County (CA), Spokane (WA), Seattle (WA), Portland (OR), Minneapolis-St. Paul (MN), St. Louis (MO), Tokyo (JP), Guadalajara (MX) and Vancouver (BC).

b) AA: American Airlines, AS: Alaska Airlines, CP: Canadian Airlines, DL: Delta Airlines, HP: America West Airline, JL: Japan Airlines, KE: Korean Air, MX: Mexicana Airlines, NW: Northwest Airlines, QQ: Reno Air, TW: Trans World Airlines, UA: United Airlines, US: US Air, WN: Southwest Airlines, OAK: Oakland International Airport, SFO: San Francisco International Airport, SJC: San Jose International Airport (CA, USA), STS: Santa Rosa.

*Table 1 Respondents and total enplaned passengers (1995)*

| Airport | San Francisco | San Jose | Oakland | Sonoma County | Total |
|---|---|---|---|---|---|
| Respondents | 10,685 | 7,069 | 3,630 | 57 | 21,459 |
| Passengers | 15,013,265 | 4,267,071 | 7,750,857 | <500,000 | |

*Table 2 Distribution of respondents according to destination (%)*

| Airport | San Francisco | San Jose | Oakland | Sonoma County |
|---|---|---|---|---|
| US | 89.6 | 96.7 | 98.6 | 90.7 |
| Europe | 3.9 | 0.6 | 0.1 | 4.7 |
| Far East | 1.0 | 0.7 | 0.2 | - |
| Australia/Oceania | 0.6 | 0.4 | 0.3 | 2.3 |
| Mexico/Caribbean/ Middle America | 1.8 | 0.6 | 0.3 | 2.3 |
| Canada | 2.7 | 0.7 | 0.3 | - |
| Other[a] | 0.4 | 0.3 | 0.1 | - |
| Total | 100 | 100 | 100 | 100 |

a South America, Middle East, Africa

*Table 3 Distribution of (origin-destination) passengers according to trip purpose (%)*

| Airport | San Francisco | San Jose | Oakland | Sonoma County |
|---|---|---|---|---|
| business | 39 | 52 | 35 | 69 |
| leisure | 54 | 40 | 54 | 26 |
| other | 7 | 8 | 11 | 5 |

*Table 4*        *Estimation results, business travelers*[1,2,3]

|  | August | | October | |
|---|---|---|---|---|
|  | I | II | I | II |
| $\alpha_f$ | 1.382* | 1.469* | 1.19* | 1.365* |
|  | (0.070) | (0.063) | (0.040) | (0.039) |
| $\alpha_s$ | 1.462* | 1.865* | 1.402* | 2.293* |
|  | (0.224) | (0.216) | (0.124) | (0.136) |
| $\beta_{SFO}$ | reference state | | reference state | |
| $\beta_{SJC}$ | -0.026 | - | -0.123 | - |
|  | (0.226) | | (0.105) | |
| $\beta_{OAK}$ | 0.144 | - | 1.406* | - |
|  | (0.379) | | (0.212) | |
| $\beta_{STS}$ | 5.021* | - | 9.098* | - |
|  | (1.539) | | (0.792) | |
| $\beta_t$ | -0.061* | -0.058* | -0.04* | -0.03 |
|  | (0.006) | (0.005) | (0.002) | (0.002) |
| $\mu_{SFO}$ | 0.854 | 0.642 | 1.359* | 0.789* |
|  | (0.101) | (0.029) | (0.072) | (0.010) |
| $\mu_{SJC}$ | 0.870 | 0.646 | 1.411* | 0.805* |
|  | (0.107) | (0.031) | (0.077) | (0.011) |
| $\mu_{OAK}$ | 0.825 | 0.612 | 1.345* | 0.768* |
|  | (0.102) | (0.031) | (0.073) | (0.011) |
| $\mu_{STS}$ | 1 (fixed parameter) | | 1 (fixed parameter) | |
| L | -2666.86 | -2670.98 | -6491.42 | -6548.17 |
| $\chi^2_\mu$ | 88.03 | 196.72 | 294.12 | 366.09 |
| $\rho^2(c)$ | 0.50 | 0.50 | 0.50 | 0.50 |
| obs. | 2129 | 2129 | 5016 | 5016 |

1) model I: with airport specific constants. Model II: without airport specific constants.
2) L is the log of likelihood. $\chi^2_\mu$ is the likelihood ratio test of the estimated model against the same model with the $\mu$'s fixed at 1. $\rho^2(c)$ (= 1-L/L(c)) is the likelihood-index. * indicates a parameter is significantly different from 0 (or 1 in case of the $\mu$'s) at the 95% confidence level. Standard errors between parentheses.
3) $\mu_d$ is the inclusive value parameter for airport $d$.

*Table 5*        *Demand elasticities, business passengers*

|  |  | SFO | SJC | OAK | STS | Bay Area |
|---|---|---|---|---|---|---|
| frequency | August | 0.86 | 0.94 | 1.24 | 0.00 | 0.93 |
|  | October | 0.85 | 1.05 | 1.05 | 0.20 | 0.95 |
| seats | August | 1.09 | 1.20 | 1.57 | 0.00 | 1.18 |
|  | October | 2.01 | 2.47 | 2.47 | 0.47 | 2.24 |
| access- | August | -0.58 | -0.21 | -1.57 | -0.01 | -0.55 |
| time | October | -0.23 | -0.18 | -0.32 | -0.07 | -0.24 |

*Table 6*        *Estimation results, leisure travelers*[1,2,3]

|  | August | | October | |
|---|---|---|---|---|
|  | I | II | I | II |
| $\alpha_f$ | 1.241[*] | 1.304[*] | 1.100[*] | 1.256[*] |
|  | (0.051) | (0.047) | (0.031) | (0.033) |
| $\alpha_v$ | 1.523[*] | 1.810[*] | 1.278[*] | 2.035[*] |
|  | (0.168) | (0.151) | (0.092) | (0.102) |
| $\beta_{SFO}$ | reference state | | reference state | |
| $\beta_{SJC}$ | 0.463[*] | - | 0.462[*] | - |
|  | (0.179) | | (0.097) | |
| $\beta_{OAK}$ | 0.113 | - | 1.513[*] | - |
|  | (0.309) | | (0.207) | |
| $\beta_{STS}$ | 4.216[*] | - | 9.381[*] | - |
|  | (1.174) | | (0.674) | |
| $\beta_t$ | -0.058[*] | -0.058[*] | -0.041[*] | -0.032 |
|  | (0.004) | (0.004) | (0.002) | (0.001) |
| $\mu_{SFO}$ | 0.852 | 0.637 | 1.443[*] | 0.777[*] |
|  | (0.083) | (0.023) | (0.067) | (0.010) |
| $\mu_{SJC}$ | 0.861 | 0.637 | 1.488[*] | 0.788[*] |
|  | (0.087) | (0.024) | (0.071) | (0.011) |
| $\mu_{OAK}$ | 0.822 | 0.604 | 1.430[*] | 0.751[*] |
|  | (0.084) | (0.024) | (0.068) | (0.011) |
| $\mu_{STS}$ | 1 (fixed parameter) | | 1 (fixed parameter) | |
| L | -4181.79 | -4189.60 | -8324.08 | -8413.11 |
| $\chi^2_\mu$ | 102.43 | 133.39 | 147.29 | 200.68 |
| $\rho^2(c)$ | 0.49 | 0.49 | 0.49 | 0.49 |
| obs. | 3281 | 3281 | 6249 | 6249 |

1) model I: with airport specific constants. Model II: without airport specific constants.
2) L is the log of likelihood. $\chi^2_\mu$ is the likelihood ratio test of the estimated model against the same model with the $\mu$'s fixed at 1. $\rho^2(c)$ (= 1-L/L(c)) is the likelihood-index. [*] indicates a parameter is significantly different from 0 (or 1 in case of the $\mu$'s) at the 95% confidence level. Standard errors between parentheses.
3) $\mu_d$ is the inclusive value parameter for airport $d$.


*Table 7*        *Demand elasticities, leisure passengers*[1]

|  |  | SFO | SJC | OAK | STS | Bay Area |
|---|---|---|---|---|---|---|
| frequency | August | 0.85 | 0.90 | 1.11 | 0.00 | 0.91 |
|  | October | 0.79 | 1.01 | 0.94 | 0.37 | 0.88 |
| seats | August | 1.18 | 1.25 | 1.54 | 0.01 | 1.26 |
|  | October | 1.84 | 2.37 | 2.19 | 0.87 | 2.05 |
| access- | August | -0.70 | -0.35 | -1.89 | -0.02 | -0.76 |
| time | October | -0.26 | -0.35 | -0.38 | -0.38 | -0.31 |

1) Elasticities for August calculated using the model without the airport specific constants.

[i] $F(U_i) = \exp(-\exp(-\frac{1}{\alpha}(U_i-\eta)))$, where $\eta$ is a location parameter and $\alpha$ is a positive scale parameter.

[ii] In theory, in a NMNL there are two scale parameters, where the scale parameter for the upper level (equation (5), the airport choice) is larger than the scale parameter for the lower level (equation (4), the airline choice). For econometric purposes, 1 parameter is scaled to one, in this case the parameter for the upper level. As then the exponents in equation (5) are devided by 1, this parameter is not reported.

[iii] These can be downloaded from: www.bts.gov.

[iv] The choice sets for August are almost the same; in the August choice set Tower Air (operating from SFO) is included, Air Canada (SFO), Northwest (OAK) and Asiana Airways (SFO) are missing.

[v] In theory, the airport tax also should be included as an explanatory variable. However, while the airport taxes differ according to the passengers status (national, international, transfer etc.), there were hardly any differences between the airports for a given passenger type in the choice set. The taxes therefore can be treated as a constant.

[vi] There are two types of test for the IIA (Fry and Harris, 1998). First, there are the choice set partitioning tests, which exploit the fact that under the IIA, irrelevant alternatives do not matter. Second, there are the alternative model tests, which test the MNL against models which do not have the IIA (e.g. the NMNL). The second type is used here.

*5₂-03*

*c ⅟o ⁰ ✗ ✗*

# LIBERALISATION OF THE WESTEUROPEAN AVIATION: CHOICE OF A NEW HUB AIRPORT FOR AN AIRLINE

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# 1 INTRODUCTION

The European air transport system consists of the airports, air traffic control and airlines. The physical characteristics and traffic volumes of the European air transport system have been impressive. According to data provided by A.E.A. (Association of European Airlines), over 210 airports have operated in the Western Europe. In the EU (European Union) countries over 100 airports have served the annual traffic overcoming more than 250000 air passengers and 10000 tonnes of air cargo (104 cities have been served by 110 airports). The European air traffic has been controlled by 45 Air Traffic Control centres which have been sub-divided into 191 low-altitude and 212 high-altitude sectors (CEC,1994). More than 200 airlines have operated at the Western European airports (approximately 145 of them have managed their flights within the EU Member States). They have carried out about 50% of all services as scheduled services. The most famous European airlines have been 22 'flag-carriers'. They have scheduled their flights on the main inter-European and intercontinental routes. The largest airlines have been Lufthansa, British Airways and Air France. Each of them has transported more than 28 million passengers per year (ATAG, 1996; Janić, 1996). The European aviation market represents an important part of the world's aviation market. The following figures support this assertion (ATAG, 1996). In 1993 the total air transport demand was nearly 390 million of passengers. Domestic scheduled and charter traffic represented about 30% of this total. International scheduled traffic shared a little bit more than 50% of the total. International charter participated in this total with about 20%. Whole region shared around 54% of the total world-wide international scheduled traffic. More than a half of these passengers travelled over Europe. For years, the dominant inter-European traffic flows have run between UK (United Kingdom) and France (around 6,2 million), UK and Germany (5,13 million), and UK and Ireland (4,3 million), (ATAG, 1996).

The relationships between the airlines operating in the European air route network have been regulated for years by more than 200 bilateral agreements (Button and Swann,1991). In 1987 the process of gradual liberalisation (deregulation) of the EU (European Union) aviation markets started. It has lasted for the past decade (1987/1993/1997). The process has been performed by implementation of three 'Aviation Liberalisation Packages' which provided institutional (legislative) conditions for free operations of the EU airlines over the area of Member States. Although they have completely started to be in effect from January 1993 the last barrier has been removed in April 1997. After that time, as in US the airlines have become freed to fly anywhere they want (between any two points) within the EU, set-up the airfares and enter or leave from the particular markets (routes).

The national flag airlines have been consolidating their domestic hub-and-spokes networks for years. After full liberalisation (deregulation) of the EU market, some of them will intend to strength their presence in the 'core' area of Europe (IFAPA, 1988; Janić, 1996). Besides the merging and alliances this will be carried out by establishing of a new hub airport in the 'core area'.

The objective of this paper has been to develop the methodology which will be able to support easier, more transparent and consistent choice of a new hub airport by an airline.

Besides this introductory section, the paper consists of five sections. Section 2 describes the 'Liberalisation Packages' concerning the EU aviation market. As well, it contains description of the main developments of this market that have happened for the past decade. Section 3 deals with the problem of 'crossing the national borders' by the airlines during 'transition' period. Section 4 covers the proposed methodology for evaluation of the 'preferable' location of new 'hub' airport. Section 5 contains the numerical example. The last Sections (6) represents the conclusions.

# 2 LIBERALISATION OF THE EUROPEAN UNION (EU) AVIATION MARKET

The main legislative basis for the operation of the world's aviation industry has been contained in the Chicago Convention (1944). This document has determined basic traffic rights guaranteeing five different 'freedoms' to the scheduled and non-scheduled (charter) airlines. These have been the following: permission for flying over a country without stopping, landing and/or taking-off due to technical reasons (e.g., to take fuel, change crew, etc.), taking passengers and freight from the country of origin to another foreign country, taking passengers and freight from the foreign country to their home country, taking passengers and freight from the foreign country to the third country, and vice versa (ICAO, 1988; OECD, 1988).

The first two 'freedoms' not involving commercial rights have been contained in the airline multilateral agreements. The other three 'freedoms' have been granted in bilateral agreements contracted between particular countries. They have been based on Bermuda Agreement reached between US and United Kingdom in 1946. According to the study carried out by ICAO (1988), the main objective of a typical bilateral agreement has always been to protect general national and specific interest of domestic airline. This has created solid regulatory structure being justified only to a certain level of development of the aviation industry (for instance, in U.S. until 1978, in Europe until 1987, etc.) (Button, 1989 a,b; Stasinopoulos, 1992, 1993; Vincent and Stasinopoulos, 1990).

In 1978 the US domestic aviation market was deregulated by single Act. Over the night, the US airlines were allowed to fly everywhere they wanted and set up freely the airfares. In addition, these airlines were discontinued any sort of governmental subsidies for non-profitable services (Bailey et. all., 1985). Liberalisation of the EU aviation market has been carried out as 'gradual' process through three phases. Each phase was determined by implementation of one 'Liberalisation Package'. This process was completed in April 1997 (Janić, 1996; Nijkamp, 1996; Stasinopoulos, 1993).

Several studies have dealt with the changes of the Western European airline industry while being liberalised. Particularly, the two of them have emerged as interesting cases (EC, 1996; Janić, 1996). The study of Janić (1996) has dealt with the analysis and modelling of the EU airline behaviour in the period 1987/1993. At that time two 'Liberalisation packages' were in effect and the third one was launched. The study of EC (European Commission) (1996) has analysed the impacts of final stage of the market liberalisation on the development of aviation industry in period 1993/1996. The study has been intended to appraise progress so far and outline eventual future actions.

The first study has analysed the airline behaviour conditioned by the institutional changes of the market. This behaviour has been characterised by the airline growth, entering the various types of mergings and alliances, alleviation of direct and strengthening indirect competition on the routes connecting the EU and the rest of the world, co-operation and/or competition, and relationships with the other transport modes operating over the are of Member States. The outcome has exhibited the following: the West European scheduled airlines have been continuously increasing the volume of their output. Mergings and alliances have been practised by many of them in order to easier cross the borders of domestic(national) markets, provide more reliable feeding of return flights, start indirect and alleviate direct competition with the other airlines on domestic market(s). Furthermore, the average airline market share, capacity share and number of airlines operating on the average route of the EU air network have been relatively stable during observed period (1989/1993). Only the capacity of an aircraft flying on the network has slightly increased. The quality of service has improved due to increasing of the flight frequencies which have

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shortened the average schedule delay (i.e., 'defer' time). This improvement has been identified as the most transparent gain for the passengers during the first phase of market liberalisation. The airfares have been more dependent on the characteristics of passengers, routes and aircraft than on the market conditions.

The EC study (EC, 1996) has confirmed the fact that the liberalisation of the EU aviation market has been carried out as gradual process. It has indicated that the most important airlines have still survived in the market. The alliances within the EU have continued both the past European and international trend. At the same time the market has become more dynamic with respect to the new entry and exit of particular airlines. For example, 20 new airlines have started business during observed period (80 new airlines have entered the market, 60 have left from the market). The market has been entered mainly by the smaller airlines. The number of routes has risen from 490 to 520. In 1996 around 30% of the EU routes have been served by two operators and only 6% by three operators in comparison to 1993 when only 2% of routes have been served by three operators. Market share of dominant airline has fallen to the advantage of second airline. The airfares have fallen on the routes where three airlines have competed. Since the most of domestic routes sharing about 80% of the total scheduled market (RPK-Revenue Passenger Kilometres) have been excluded from the liberalisation process until April 1997, this fall has been modest .

## 3 CROSSING THE NATIONAL BORDERS

### 3.1 Mergings and alliances

In order to easier 'cross' the national borders and expand their markets, many of the Western European airlines have widely contracted the various mergings and alliances. Particularly this type of co-operation has enhanced during the first phase of the liberalisation of the EU market (period 1987/1991) as well as afterwards.

Generally, three types of the airline mergers have been developed (Tretheway, 1990). These are: *corporate mergers, simple airline alliances of type 'marketing agreement'*, and *strong airline alliances* involving holding of stakes or equities by merger(s) in the partner(s).

Table 1 shows an example of the merging and alliances contracted by some of the EU scheduled airlines (Janić, 1996). As it can be noticed, the number of alliances of type 'marketing agreement' has been greater than the number of those contracted by 'holding of stakes' (or 'equity') in the partner(s). The larger airlines as the mergers have contracted a greater number of alliances of both types than the smaller ones. Particularly, the airlines originating from the European 'peripheral' regions (countries) like Alitalia, Austrian Airlines, British Midland, SAS and TAP-Air Portugal have contracted more alliances than it could be expected considering their size, scale and volume of operations.

Air France has contracted the most alliances of type 'holding of stake' with domestic smaller non-flag airlines, the European regional airlines and the partners from the France's former colonies. Air France, Iberia, Lufthansa, British Midland, SAS and Swissair have contracted approximately the same number of alliances of type 'marketing agreement' with the partners from Europe and other continents. Austrian Airlines and KLM have contracted much more alliances of type 'marketing agreement' with the European than non-European partners. Alitalia has done a quite opposite in comparison to them.

Several reasons have driven the leading EU flags to enter the 'strong alliances'. First, they have simultaneously intended to 'enlarge' and 'consolidate' their markets at home and abroad. Their partners have been expected to be capable to efficiently 'feed' the mergers' continental and intercontinental flights and build the efficient 'barriers' being capable to

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*Table 1. Mergings and Alliances of the European Airlines (1995)*

| Airline | Number of mergers and alliances by type[*] | | | | | |
|---|---|---|---|---|---|---|
| | $A_0$ | $A_{01}$ | $A_{02}$ | $A_1$ | $A_{11}$ | $A_{12}$ |
| Air France | 16 | 9 | 7 | 13 | 4 | 9 |
| Alitalia | 6 | 1 | 5 | 1 | 1 | 0 |
| British Airways | 5 | 2 | 3 | 3 | 2 | 1 |
| Cyprys Airways | 5 | 2 | 3 | 0 | 0 | 0 |
| Iberia | 23 | 11 | 12 | 4 | 1 | 3 |
| KLM | 10 | 7 | 3 | 3 | 1 | 2 |
| Lufthansa | 22 | 10 | 12 | 4 | 4 | 0 |
| Luxair | 0 | 0 | 0 | 1 | 1 | 0 |
| Sabena | 1 | 1 | 0 | 1 | 0 | 1 |
| SAS | 7 | 3 | 4 | 2 | 2 | 0 |
| Swissair | 5 | 2 | 3 | 4 | 2 | 2 |
| Austrian Airlines | 15 | 12 | 3 | 3 | 2 | 1 |
| British Midland | 9 | 4 | 5 | 2 | 1 | 1 |
| TAP Air Portugal | 5 | 2 | 3 | 0 | 0 | 0 |

[*] $A_{0i}$ - *Mergings and alliances without holding of stakes or equity in the partner;* $A_{1i}$ - *Mergings and alliances with holding of stakes or equity in the partner (i = 0, the total number; i = 1, the number with the European partners; i = 2, the number with non-European partners). Sources: Airline Business, 1995; Janić, 1996.*

alleviate and/or even completely prevent competition of the other smaller non-flag airlines and new entrants. Second, the 'strong alliances' have provided the mergers more efficient access to the strategically positioned airports (e.g., the hub(s) of their partner(s)). Additionally, they have used this opportunity to indirectly enter the domestic markets of the other flags and start indirect competition with them (IFAPA, 1988; Janić, 1996; Tretheway, 1990).

## 3.2 The need for establishing of new 'hub' airport

In order to easier understand the motivation of the particular airlines to establish new 'hub' let us briefly look at the main characteristics of their businesses that have been developed during the past decade.

First, the market of European scheduled flag airlines has been constrained by the 'national' borders for years. Under such conditions the international services have been determined by the 'strict' bilateral agreements contracted between the airlines and their states. They have provided the institutional rules for 'crossing' of the country's borders. In order to alleviate these limitations the airlines have entered the mergings and alliances which have been shown later on as convenient but inherently non-competitive 'tool'. Second, the EU airlines have already operated the 'hub-and-spoke' networks consisting of both domestic and international routes originated from single domestic 'hub'. Particularly, at the US airlines the 'hub-and-spoke' networks have shown to be the most beneficial than the other ones (Morrison and Winston, 1986). Furthermore, this configuration has appeared to be a relatively powerful deterring 'tool' for the airlines facing with potential new entries. The last, the most of the EU flag airlines have been governmentally owned. Such kind of ownership has produced twofold effect at these airlines. On the one side, they have been managed in a relatively 'rigid' manner by serving, apart from their own, also to some other interests. On the other side, such management policy has prevented development of the more flexible services that would be capable to match much better potential demand. The

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awards (subsidies) for non-profitable services have been common element of such policy. This has prevented the 'actual concentration' of demand and supply on the level of industry. Hence, the market liberalisation has been expected to diminish and even completely remove such 'market deviations', as well as to 'speed-up' constitution of the 'free' aviation market. Nevertheless, some hindering limitations have still remained. At least three reasons support these doubts. First, the airlines are expected to further strengthen their existing 'hub-and-spoke' networks. This will be realised by increasing of the flight frequencies on the existing routes (markets), entering new markets (routes) to/from the hub and more efficient co-ordination of the inbound and outbound flights at the 'hub'. Second, the most of the flags are going to leave their basic activities on the existing 'national' base. Third, inherent instability of some types of mergings and alliances will be sustained.

Therefore, in order to reduce the uncertainty of such arrangements and provide full operational 'independence' the airlines are expected more intensively to use the free access to the 'foreign' markets where there may be the opportunity for establishing a new hub(s). Particularly, the airlines whose existing hubs have been 'peripheral' in relation to the European 'core' area are expected to benefit from the new option(s). The 'core' area of Europe has commonly been defined by the central parts of France and Germany, south part of England, Belgium and the Netherlands, and North Italy. Evidently, it has generated about 35% of the total European air traffic (IFAPA, 1988). Essentially, the establishment of new (second) hub airport in the 'foreign' Member State will represent the other possibility for crossing the 'national' borders. This has become more certain today than some time ago due to at least four reasons: First, the inclusion of domestic markets (routes) into the liberalisation 'quota' (in April 1997) has created the institutional conditions for an unlimited presence of any of the EU airlines at any of the EU airports. Second, the most airports have started to operate according to more markedly oriented principles which have included much easier acquisition of landing and taking-off slots as well. Third, privatisation of the particular airport services like ramp-handling, fuel services, etc., has made these airports more attractive for the airlines looking for a 'new' hub. Last, the 'grandfather's rights' kept by the 'incumbents' have not represented anymore the institutional barrier for the new entrants.

Evidently, the practice of looking for new hub has already begun. For example, Iberia (its hub is the airport Madrid-Barajas) has considered the airports Frankfurt and Amsterdam-Schiphol as potential 'new' hubs. Finnair whose hub has been at the airport Helsinki-Vantaa has considered the airport Stockholm-Arlanda as potentially new ('secondary') hub. Both SAS which has already operated three 'hubs' (Copenhagen, Stockholm-Arlanda, Oslo-Fornebu) and KLM has looked for location of the 'new' hubs (Berechman and Jaap, 1996). Currently, all these airlines operate the 'national' ('domestic) hubs that are located in the peripheral European regions.

## 4 THE EVALUATION METHODOLOGY

Several studies have dealt with the problem of designing of the 'optimal' hub-and-spoke transport network. They have been developed in different fields like operational research, spatial planning and economics. Usually they have followed the real-life developments and achievements of the hub-and-spoke systems in both, the passenger and freight transport (Aykin, 1995). In particular, the operational researchers have considered the problem of determining the route structure and location of one or few hubs as the problem of minimisation of the total network cost imposed on the enterprise(s) in question. A single hub location problem has been always converted into the classical Weber least cost location

problem. The problem of optimal location of two or more hubs has emerged to be much more complex. It has requested the development of specific and complex algorithms based on heuristics and mathematical programming (Aykin, 1995; Daskin, 1995; O'Kelly, 1986). The most of the economists have applied regression model(s) for studying of the development of hub-and-spoke networks and their impacts on the operators' and users' welfare. For example, the study by Morrison and Winston (1986) has shown that the public has particularly benefited by introducing of the hub-and-spoke networks. The public has enjoyed joining the more frequent flights on the particular routes, lower airfares and overall shorter travel times. In this study, the hub-and-spoke network has been considered as the problem which has not dealt with the location of hub. Some other researchers have a priory ('logically') stated that the hub(s) should be centrally located, in particular nearby the sites which have been capable to generate the significant volumes of local traffic (Bailey, Graham and Kaplan, 1985). The most recent paper of Berechman and Jaap (1996) has developed the simulation model for choosing of the optimal location of hub airport by the hypothetical West European airline. The 'potential profits', that could be earned by operating of the hub-and-spoke network 'rooting' from the selected hub airport, has been applied as single criterion in decision making process.

In the present paper the multi criteria approach for choice of the 'secondary' hub airport of an airline has been elaborated.

## 4.1 Description of the attributes (criteria)

A finite number of the airports might be considered by an airline as the potential alternate locations of new hub. Each airport has been assigned three sets of relevant criteria (attributes). These have been the following: the airport background, the airport specific (local) characteristics, and the cost imposed on an airline due to incorporating of an airport (alternative) into its air route network.

*The airport background* is represented by general social-economics characteristics of the area where it is located. These are: the number of population living in the airport catchment area; GDP and/or per capita income of the region (country) served by the airport; rank of the area (region, country) and city (cities) in business; intensity of cultural, recreational and general tourist activities, etc.

Generally, the population of the airport catchment area may reflect its potential to generate 'local' air travel demand. Hence, the airports serving the larger and more populated hinterlands are expected to serve a greater volume of local traffic. In the most countries GDP (Gross Domestic Product) and per capita income have been identified as the main driving forces of the aviation activities. This fact can be analogously applied to the region around the airport in question (i.e., on its catchment area). Therefore, a higher GDP will generate a grater volume of the business and leisure activities and thus a greater air travel demand. In addition, the tourist attractions and famous cultural events organised in the sites nearby the airport may also generate a greater air travel demand.

*The airport attributes* can be classified into three sub-sets. The first sub-set is represented by the characteristics of services provided at the airport land-side area. These are: the number of available airport ground access systems (modes), distance, time and unit cost of travel to/from the airport, as well as the availability (accessibility) of interconnections to the services provided by other transport modes at both national and international level (for example, the rail station at an airport may enable interchange of the passengers between air and rail mode at local, national and international level). The second sub-set represents the airport general characteristics like the volume of traffic (it can be expressed by the number

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of passengers and aircraft movements, and volume of cargo), structure of this traffic (local-national, international; origin/destination, transit/transfer passengers, cargo and aircraft movements exist), and the average unit cost per service. The last sub-set of attributes represents the physical and operational characteristics of the airport air-side area like the available and planned capacity and its utilisation and distribution of the slots among the airlines already operated on the airport.

Accessing and leaving from the airport have emerged to be the important criteria (attributes) for the passenger's choice of an airport among a few ones serving large agglomerations (Ndoh, 1995). Evidently, the airport served by a greater number of the more efficient (closer, faster, and cheaper) ground access modes will be preferable while being considered as potential new hub by an airline(Ashford, 1988).

The airports already serving a greater volume of traffic inherently possess a higher attractiveness than those serving the smaller ones. Without doubt the same trend will continue in the future. As a result, the larger airports will always remain to be more attractive than the smaller ones. The structure of traffic at an airport reflects its relative position and importance in the airport network. A higher level of diversity of destinations and heterogeneity of traffic concerning its origin and destination may make an airport more attractive. Concerning the long-term business policy of an airline the cost per unit of service at an airport can influence on its attractiveness. Naturally, the airports with lower unit charges will be more attractive for all airlines (Doganis, 1992). Both the airport capacity and its utilisation reflect the opportunity for an airline to easier get a desired number of landing slots and supporting ground (gate) services. Generally, the airport with greater spare capacity will be more convenient for the airlines. Furthermore, the distribution of available slots among the airlines already operated at the airport reflects the level of 'market deregulation' including 'the relative market strength' of the incumbent. If the slots are more uniformly distributed among these airlines the airport will be considered by a new entrant as more 'liberal' (Janić, 1996).

*The airline network attributes* are represented by the routing strategies which can be applied by the airline in order to incorporate the chosen hub airport in its air route network. Choice of the airport location and corresponding routing strategy can be carried out either in order to minimise the airline total cost or maximise potential revenues (profits).

## 4.2 Modelling of the attributes (criteria)

The most of specified attributes (criteria) have not needed any modelling. They have been able to be simply estimated by using of the real-life data. Then, they have been applied as the attributes in the evaluation procedure. Nevertheless, several exceptions have still existed. One of them has been represented by the generalised cost which might be imposed on the passengers during access and leaving from the airport. The model of relevant generalised cost function can be represented as follows:

$$c_g = p(d) + \alpha T(d) \qquad (1)$$

where

$p(d)$ is the fare charged to the passenger for use of one among the available airport ground transport modes (ECU/km),

$d$ is the average travel distance between the airport and its catchment area,

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$\alpha$ is the unit value of the passenger time (ECU/unit of time/passenger),

$T(d)$ is the perceived travel time on the route $d$ connecting the airport with its catchment area $(T(d) = d/v(d)$, where $v(d)$ is the average speed of chosen transport mode over distance $d$).

Additionally, the attributes of airline network have required the explanation and modelling. Both have been performed by taking into account the specific conditions prevailing in the European aviation market.

Evidently, the Westeuropean air route network of scheduled services can be divided into three sub-networks. These are: domestic, intra-European and intercontinental sub-network (Janić, 1996). These sub-networks have been composed of the networks operated by different airlines. The 'hubs' of the particular airlines have been located at different places (nodes) of the integral network. Some of them have been closer to the network's centre (e.g., to the 'core' area of Europe). Some of them have been located on the network's periphery. Many 'peripheral' locations have been identified as inappropriate for further development of successful competition between these and the other airlines. A simplified example of the network operated by a 'peripheral' airline in shown in Figure 1. It indicates that the airline hub is located in the country of its origin. The spokes are located in the other (foreign) European countries. Due to regulation being in effect until 1997 the airline has been only allowed to schedule direct (non-stop) flights between its hub and particular spokes. Establishment of direct connections between particular spokes has not been possible, whereas the indirect connections established between spokes through the hub have produced a little benefit due to great detours of the passengers. Under such conditions these passengers have rather decided to use the flights of the airlines flying directly between the spokes in question. As it can be noticed these flows have been lost for the considered airline. These losses have been equivalent to: $(N(N-1) - 2(N-1)) = N(N-3)+2$, where $N$ is the number of spoke airports in the airline network. In order to attract these flows and thus improve its 'peripheral' position the airline has been forced to look for location of the 'European' hub which would be closer to the centrally located site with regard to the location of the existing spokes and 'old' hub. If this airline has been assumed to apply a 'strict' routing policy in order to connect 'new' hub and 'old' spokes, each spoke will be assigned to 'new' hub for all inbound and outbound services (Aykin, 1995; O'Kelly, 1986). Additionally, direct connections between the 'old' hub and spokes will be completely abandoned. This will enable the airline to funnel the inter-spoke flows through 'new' hub. In this context, the 'old' hub will become only a 'strong' spoke. Figure 2 schematically illustrates possible change of the network layout due to relocation of the hub.

'New' network possesses the advantages and disadvantages in comparison to the 'old' one. Particularly with respect to the characteristics of traffic on the particular routes. The advantages are the following: the volume of demand in the airline system will increase thanks to attracting of the inter-spoke' passenger flows and local flows running between new hub and the spokes. The volume of passenger flows on each route will be increased since the flows from the same origin(s) to the different destinations will be consolidated on the inbound route(s) to the 'new' hub, and the flows with different origins to the same destination(s) will be consolidated on the outbound route(s). The increased density of passengers on the particular routes will justify the increase in the flight frequencies and using of the larger aircraft. A higher flight frequencies will shorten the passenger schedule delays and thus reduce the inconvenience of journey due to passing through the hub. As the
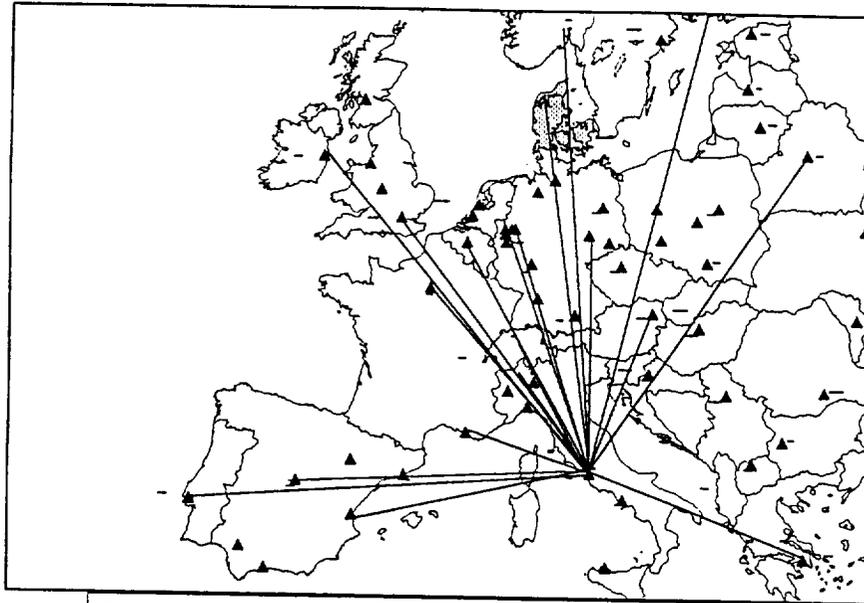
*Figure 1. Scheme of the route network of a 'peripheral' airline*
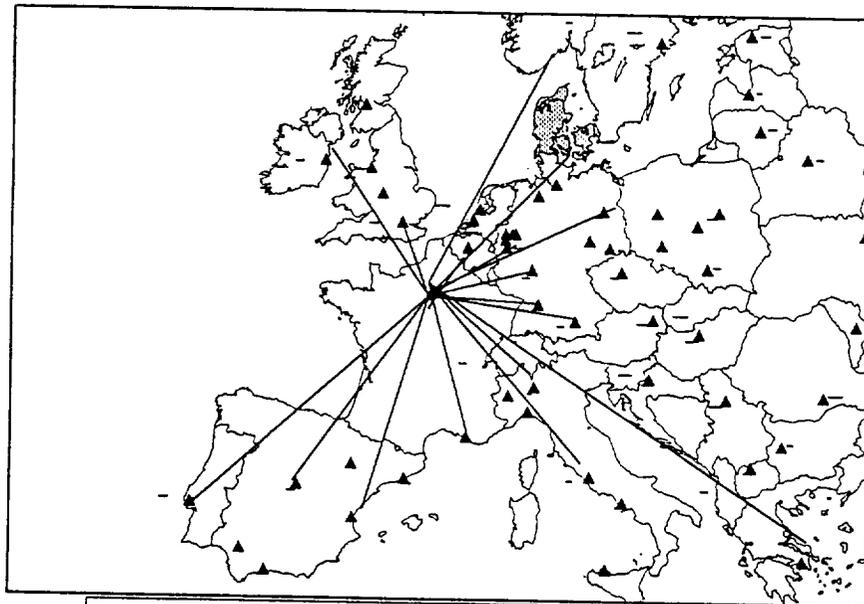


*Figure 2. Scheme of the airline network established around the new hub airport*

larger aircraft are used the effects of economies of scale will emerge. Considering the cost per unit of flow (e.g., the cost per passenger) they may diminish with increasing of the volume of passengers and seats on the route. The lower costs may enable the airline to offer the more competitive airfares. Additional advantage is represented by an increase in the number of destinations for a greater number of passengers.

The crucial disadvantage of this concept is represented by the longer (extra) travel distances and travel times which the passengers should pass while being in the network. They all have to make a longer and less convenient detours through the 'new' hub in order to reach the 'old' hub as well as the other spokes (destinations).

One of the most important criteria for choice of the new hub is minimisation of the total cost of new network system. This criterion can be modelled as follows (O'Kelly, 1986).

Let us denote the flows between the pairs of airports (the nodes of an airline network) by $Q_{ij}$ $(i, j = 1, 2, ...,N)$. It is assumed that $K$ sites for locating 'new' hub can be considered. Each location can coincide or not with existing nodes. Let we assume that each origin airport is also destination airport (node). The objective is to:

$$\text{Min}_K \left[ \sum_i \sum_j Q_{ij}(c_{iK} + c_{Kj}) \right] \tag{2}$$

where

$c_{iK}, c_{Kj}$ is the cost per unit of flow (passenger) to connect the nodes $(i)$ and $(j)$, respectively, with location $K$.

Let $Q_i = \sum_j Q_{ij}$ to be the total outflow from the origin airport $(i)$, and $D_j = \sum_i Q_{ij}$ to be the total inflow to the destination airport $(j)$. The problem (2) can now be simplified as follows:

$$\text{Min}_K \left[ \sum_i c_{iK} \sum_j Q_{ij} + \sum_j c_{Kj} \sum_i Q_{ij} \right] = \text{Min}_K \left[ \sum_i c_{iK} O_i + \sum_j c_{Kj} D_j \right] \tag{3}$$

The expression (3) represents the classical Weber least cost location problem. Furthermore, let $A_i = O_i + D_i$ to be the total share of the location $(i)$ in all flows. The expression (3) can now take the following final form:

$$\text{Min}_K \left[ \sum_i c_{iK} A_i \right] \tag{4}$$

One of the available algorithms to solve the problem (4) has been based on complete enumeration of all $K$ locations of 'new' hub.

Actually, the term $c_{iK} A_i$ in the expression (3) represents the total cost of serving the flow of passengers on the route connecting the spoke $(i)$ and hub $K$. If the airline is assumed to schedule the flights on each route in order to minimise the total cost consisting of its operational cost and cost of the passenger schedule delay, the term $c_{iK} A_i$ will be transformed as follows (Janić, 1993; Yeng, 1987):

$$c_{iK} A_i \equiv \left[ 2\alpha T c_f(N_{iK}, d_{ik})(A_i) \right]^{0.5} \tag{5}$$

where

$\alpha$ is the average value of passenger time during the waiting for the first available departure,

$T$ is the period when the flights are available on the route $(iK)$,

$c_f(N_{ik}, d_{ik})$ is the average cost per flight carried out on the route $d_{ik}$ by the aircraft of seating capacity $N_{ik}$,

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From the above expression it can be noticed that the route cost will increase with increase in the value of the passenger time, aircraft capacity, route length, and total volume of demand. Simple mathematical manipulation can be applied to show that the average and marginal cost per unit of flow on the route (cost per passenger) will decrease more than proportionally with an increase in the volume of demand as it follows:

$$Ac_{iK} = \left(2\alpha T c_f (N_{iK}, d_{iK}) / A_{iK}\right)^{0,5}, \text{ and}$$

$$Mc_{iK} = \partial / \partial A_{iK} \left[2\alpha T c_f (N_{iK}, d_{iK}) A_{iK}\right]^{0,5} = 0,707 \left[2\alpha T c_f (N_{iK}, d_{iK}) / A_{iK}\right]^{0,5}.$$

Evidently, the economies of scale on the routes connecting the 'new' hub and other spokes may exist. This may allow the airline to set up lower and more competitive airfares.

## 4.3 The multiattribute evaluation method - the TOPSIS

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is one among the methods suitable for making a choice of the preferable among few alternatives (Hwang and Yoon, 1981). To be successfully applied, this method requests 'weighting' of the attributes (criteria) assigned to the particular alternatives. These weights can be quantified either empirically (by interviewing of the representatives of the airline) or by using of the convenient analytical methods (like in this case). The entropy method has been commonly applied for assessing the weights to attributes (Hwang and Yoon, 1981). This method has assumed that the data on the decision matrix containing the quantitative estimates of criteria of each alternative have been known. Let the alternative $A_i$ $(i = 1,2,3,..., m)$ should be evaluated according to $(n)$ criteria (the attributes) $(X_j, j = 1,2,3, .. n)$. Let $X_{ij}$ to be the outcome of the $i$-th alternative with respect to the $j$-th criterion. The value of $X_{ij}$ in the decision matrix $D$ contains certain information. Let $p_{ij}$ to be the probability that the alternative $A_i$ is 'preferable' per criterion $X_j$. This probability can be determined as follows:

$$p_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}, \forall (ij) \tag{6a}$$

Since the choice of 'preferred' alternative with respect to criterion $X_j$ is related to some measure of the uncertainty, the entropy of criteria $E_j$ can be expressed as follows:

$$E_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{ij} \ln p_{ij}, \forall j \tag{6b}$$

where the expression $[1/\ln(m)]$ guarantees that the condition $[0 \leq E_j \leq 1]$ will be fulfilled. If Decision Maker (DM) has not a reason to prefer one criterion over the other ones the weight of criteria $X_j$ can be determined as follows (Hwang and Yoon, 1981):

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)}, \forall j \tag{6c}$$

The TOPSIS method evaluates decision matrix $D[X_{ij}]$ $(i =1,2,. . . ,m; j=1,2, . . . ,n)$ with $(m)$ alternatives. Each alternative has $(n)$ criteria. It is assumed that each criterion can take either increasing or decreasing utility. Hence, if the outcome from some criterion is larger, a grater preference for the 'benefit' criterion and less preference for the 'cost' criterion will be. The structure of the TOPSIS method is illustrated as follows:

*STEP1:*

The dimensions of various criteria should be converted into non-dimensional units allowing comparison across them. For that purpose the following normalised decision matrix $R$ is created (Hwang and Yoon, 1981):

$$r_{ij} = X_{ij} / \sqrt{\sum_{i=1}^{m} X_{ij}^2} \qquad (7)$$

*STEP 2:*

A set of weights $w_j$ $(j = 1,2, . . ,n)$ obtained either by the expression (6), decision maker or by both is accommodated to the weighted decision matrix which can be calculated by multiplying each column of the matrix $R$ by its associated weight $w_j$. Thus, this decision matrix takes the form: $V = [w_j * r_{ij}]$, $(i = 1,2, . . ,m; j= 1,2, . . ,n)$.

*STEP 3:*

After determining of the matrix $V$, the ideal solution $A^*$ and negative ideal solution $A^-$ can be determined as follows:

$$A^* = \left\{ \left( \max_i v_{ij} | j \in J \right); \left( \min_i v_{ij} | j \in J' \right) | i = 1,2,..,m \right\} = \left\{ v_1^*, v_2^*, .., v_j^*, .., v_n^* \right\} \qquad (8a)$$

and

$$A^- = \left\{ \left( \min_i v_{ij} | j \in J \right); \left( \max_i v_{ij} | j \in J' \right) | i = 1,2,..,m \right\} = \left\{ v_1^-, v_2^-, .., v_j^-, .., v_n^- \right\} \qquad (8b)$$

where $J$ is associated with 'benefit' and $J'$ with 'cost' criteria.

*STEP 4:*

The separation of each alternative from the ideal and negative ideal solution can be computed as follows:

$$S_{i*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \quad for \quad i = 1,2,..,m \qquad (9a)$$

and

$$S_{i-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, for \quad i = 1,2,..,m \qquad (9b)$$

STEP 5:

A relative closeness of the alternative $A_i$ to $A^*$ is determined as follows:

$$C_{i*} = S_{i-} / \left( S_{i*} + S_{i-} \right), \quad 0 < C_{i*} < 1, \quad i = 1,2,.\ .,m \tag{10}$$

It is clear that if $C_{i*} = 1$, $A_i = A^*$, and if $C_{i*} = 0$, $A_i = A^-$. In other words an alternative will be closer to $A^*$ if $C_{i*}$ approaches to $1$. A set of alternatives can now be ranked in descending order of $C_{i*}$ (Hwang and Yoon, 1981).

## 5 APPLICATION OF THE METHODOLOGY

### 5.1 Description of input

The presented methodology has been applied to a hypothetical airline assumed to operate the network consisting of a single hub and nineteen spokes. The network nodes which have been included in the network have been the famous EU cities like Amsterdam (The Netherlands), Athens (Greece), Barcelona (Spain), Brussels (Belgium), Copenhagen (Denmark), Dublin (Ireland), Dusseldorf, Frankfurt (Germany), Geneva (Switzerland), Helsinki (Finland), Lisbon (Portugal), London (Great Britain), Madrid (Spain), Milan (Italy), Munich (Germany), Oslo (Norway), Paris (France), Rome (Italy), Vienna (Austria), and Zurich (Switzerland) .The spokes have been connected with hub by 19 direct non-stop flights (see scheme in Figure 1)..

If the network has been completely connected, the number of O/D flows has been 380. However, since the hub has been located on the network's 'periphery' (for example in Rome) it has been really to assume that only 38 of direct flows can be attracted by the airline non-stop flights connecting its hub and the spokes. The other 9/10 of the flows have been assumed to be likely served by the non-stop flights scheduled between these cites by the other airlines. In order to simultaneously attract some of these passengers and eliminate long detours which may happen due to travelling through the 'peripheral' hub, the airline has been assumed to consider the following 8 cites as the alternative locations of the new hub: Amsterdam, Brussels, Dusseldorf, Frankfurt, London Milan, Madrid and Paris. The airports near these cites have served the following annual number of passengers in 1996 (million): $A_1$-Brussels (13,5), $A_2$-Paris (Charles de Gaulle-CDG, 31,7), $A_3$-Frankfurt (38,7), $A_4$-Dusseldorf (14,4), $A_5$-Amsterdam (Schiphol, 27,8), $A_6$-London (Heathrow, 56), $A_7$-Milan (Linate, 12,6), and $A_8$-Madrid (Barajas, 21,9).

The set of decision making attributes (criteria) has been estimated for each of the candidate airports.

The first two attributes have been the population and per capita income of the airport catchment area (attributes $X_1$ and $X_2$, respectively). Their values are presented in Table 2 (MS, 1997). The third attribute $X_3$ has been represented by the number of ground access modes at each airport. The data on the travel distances, timetable allowing estimation of the passenger schedule delay as well as the prices per mode have been extracted from the convenient sources (Lufthansa, 1996). Then, by applying of the expression (1) the passenger generalised cost of access/leaving from the candidate airport has been computed. The output relating to the cheapest mode has been chosen as the fourth attribute, $X_4$. Both values, $X_3$ and $X_4$ are given in Table 2.

The network established around a new hub airport has consisted of 19 non-stop routes connecting the particular places. The airline has been assumed to schedule each flight on each route in order to simultaneously satisfy expected demand and minimise the total route cost consisting of the airline operating cost and passenger time cost (see the expression (5)). As well, the airline is assumed to be confronted with the competition of three to four airlines

operating over the same network. Its market share has been assumed to be proportional to the capacity (e.g., to the seat share in the total number of seats supplied on the route by all airlines) (Douglas and Miller, 1974; Janić, 1996). In order to estimate the minimum route cost function (5) and the cost of particular hub locations (expression (4)), the 1993 data on the passenger O/D flows running between above 20 sites have been extracted (ICAO, 1995). Then, they have been aggregated according to the expression (3) and (4), and assigned to the airline network regarding the competition of other airlines on each route. By applying of the corresponding cross-sectional data the cost per flight, $c_f$ $(N, d)$ (the expression (5)) being converted into ECU per flight has been estimated as follows (Janić, 1997):

$$c_f(N, d) = 6,206 \, N^{0,603} \, d^{0,656}$$
$$(3,266) \quad (4,339) \quad (4,733)$$

$$R^2_{adj} = 0,896; \, F = 77, \, 477; \, DW = 1, \, 692; \, N = 21 \text{ [1]}$$

Then, as the aircraft of average seat capacity of $N = 145,5$ seats has been engaged on all routes of the network, the cost per flight $c_f$ $(145,5; \, d)$ has been computed for the corresponding route $d$. The period of supplying the flights has been adopted to be : $T = 16$ hours per day. This coincides with the current practice applied by the majority of the EU airports to ban the landings and take-offs during the night (usually from 10 p.m. to 6 a.m.) in order to reduce the exposure of the inhabitants cited nearby the airports to noise. The value of passenger time has assumed to be approximately equal for all passengers as follows: $\alpha = 34,4$ ECU/hour/passenger. This has implied that the passenger flows have consisted exclusively of the business passengers (CAA, 1993; Janić, 1996).

By using of the above inputs the minimum route cost and the minimum cost of location of new hub at any of the eight places have been computed (The expressions (5) and (4) have been applied, respectively). The results are presented in Table 2 as the values of the sixth attribute $X_5$.

The average cost of serving one WLU (Workload Unit) at an airport has been estimated in dependence on the annual volume of WLU. This has been carried out in two steps: First, the regression model has been estimated by using of the appropriate cross-sectional data for 30 airports world-wide (Airline Business, 1995). The model has taken the following form.

$$C(W) = 72,366 \, (W)^{-0,882}, \, R^2 = 0,561, \, N = 30$$

Then, the average cost per WLU has been computed by inserting corresponding annual volume of WLU. The outputs corresponding to each alternative are presented in Table 2 as the sixth attribute $X_6$ (ACI, 1997).

The market share of the incumbent airline at the candidate airports has been estimated by division of the number of incumbent's flights with the total number of weekly flights realised there (ABC, 1995). The results are presented in Table 2 as the values of the seventh attribute $X_7$. In addition, the average utilisation of the reported airport capacity has been presented in Table 2 at the eight attribute $X_8$ (CAA, 1993; Urbatzka and Wilken, 1997).

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[1] Evidently, $t$-statistics given in parenthesis bellow particular coefficients indicate that both independent variables, the aircraft seating capacity and length of non-stop route are significant at 1% and 5% level. In addition, whole equation is significant ($F$-value). Both variables have important and significant explanatory power ($R^2$ value). Auto-correlation between the chosen independent variables has not been detected ($DW$- Durbin -Watson statistic).

## 5.2 Discussion of the results

Table 2 has taken over the role of Decision Matrix (DM) allowing the carrying out of four computational steps of the TOPSIS method as follows.

*Table 2: The list of alternatives, attributes (criteria) and their values in a given example (Multiple Criteria Decision Matrix)*

| Alternatives | Attributes (Criteria) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Airport** | **POP** | **PCI** | **NAM** | **GAC** | **LC** | **CWL** | **MS** | **UC** |
| | $\underline{X_1}$ | $\underline{X_2}$ | $\underline{X_2}$ | $\underline{X_4}$ | $\underline{X_5}$ | $\underline{X_6}$ | $\underline{X_7}$ | $\underline{X_8}$ |
| A$_1$-Brussels | 1,1 | 15423 | 2 | 13,28 | 1,56 | 5,16 | 62 | 77 |
| A$_2$-Paris | 9,3 | 16468 | 2 | 21,73 | 1,61 | 2,71 | 42 | 74 |
| A$_3$-Frankfurt | 3,6 | 18308 | 3 | 8,12 | 1,62 | 2,16 | 55 | 84 |
| A$_4$-Dusseldorf | 3,0 | 18308 | 2 | 9,30 | 2,18 | 6,62 | 44 | 79 |
| A$_5$-Amsterdam | 1,1 | 15111 | 2 | 8,32 | 1,65 | 2,84 | 53 | 68 |
| A$_6$-London | 7,3 | 13293 | 3 | 21,64 | 1,68 | 1,76 | 42 | 93 |
| A$_7$-Milan | 4,3 | 15589 | 2 | 14,47 | 2,25 | 7,37 | 58 | 59 |
| A$_8$-Madrid | 4,1 | 10568 | 2 | 17,59 | 2,48 | 4,30 | 61 | 76 |

POP - Population of the airport catchment area (million of inhabitants); PCI - Average per Capita Income (ECU/inhabitant); NAM- The number of available airport ground access modes; GAC - Minimum generalised airport access cost (ECU/passenger); LC - Minimum location cost of new hub (million ECU); CWL - Average cost per Workload Unit (ECU/WLU); MS - Market share of the incumbent airline at an airport (%); UC- Percent of utilisation of reported airport capacity (operations per hour).

1. The normalised decision matrix R has been calculated by the expression (7) as follows:

| | $\underline{X_1}$ | $\underline{X_2}$ | $\underline{X_2}$ | $\underline{X_4}$ | $\underline{X_5}$ | $\underline{X_6}$ | $\underline{X_7}$ | $\underline{X_8}$ |
|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0,0779 | 0,3502 | 0,3086 | 0,3081 | 0,4001 | 0,2881 | 0,4160 | 0,354 |
| $A_2$ | 0,6586 | 0,3739 | 0,3086 | 0,5043 | 0,2098 | 0,2974 | 0,2820 | 0,3391 |
| $A_3$ | 0,2550 | 0,4157 | 0,4630 | 0,1855 | 0,1671 | 0,3004 | 0,3690 | 0,3879 |
| $A_4$ | 0,2125 | 0,4157 | 0,3086 | 0,2159 | 0,5132 | 0,4041 | 0,2950 | 0,3653 |
| $A_5$ | 0,0779 | 0,3431 | 0,3086 | 0,1931 | 0,2198 | 0,3056 | 0,3560 | 03147 |
| $A_6$ | 0,517 | 0,3018 | 0,463 | 0,5023 | 01367 | 0,3087 | 0,2820 | 0,4261 |
| $A_7$ | 0,3045 | 0,3540 | 0,3086 | 0,3358 | 0,5715 | 0,4172 | 0,3890 | 0,2701 |
| $A_8$ | 0,2904 | 0,2400 | 0,3806 | 0,4081 | 0,3340 | 0,4594 | 0,4090 | 0,3500 |

2. A relative importance of the particular attributes expressed by their 'weights' has been calculated from the expression (6) as follows:

$$\underline{w} = \{w_i / i = 1,2,...,8\} = \{0,4434; \ 0,0283; \ 0,0377; \ 0,0132; \ 0,2594; \ 0,0377; \ 0,0425; \ 0,0189\}$$

Then, the weighted decision matrix $V$ has been computed as follows:

Then, the weighted decision matrix $V$ has been computed as follows:

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0,0337 | 0,0098 | 0,0114 | 0,0397 | 0,1012 | 0,0107 | 0,0140 | 0,0060 |
| $A_2$ | 0,2852 | 0,0105 | 0,0114 | 0,0651 | 0,0529 | 0,0110 | 0,0100 | 0,0060 |
| $A_3$ | 0,1104 | 0,0116 | 0,0171 | 0,0239 | 0,0423 | 0,0111 | 0,0130 | 0,0070 |
| $A_4$ | 0,0920 | 0,0116 | 0,0114 | 0,0279 | 0,1298 | 0,0150 | 0,0100 | 0,0070 |
| $A_5$ | 0,0337 | 0,0096 | 0,0114 | 0,0249 | 0,0556 | 0,0113 | 0,0120 | 0,0060 |
| $A_6$ | 0,2239 | 0,0085 | 0,0171 | 0,0648 | 0,0037 | 0,0114 | 0,0100 | 0,0080 |
| $A_7$ | 0,1319 | 0,0099 | 0,0114 | 0,0391 | 0,1446 | 0,0154 | 0,0130 | 0,0050 |
| $A_8$ | 0,1258 | 0,0067 | 0,0114 | 0,0256 | 0,0850 | 0,0170 | 0,0140 | 0,0060 |

3. The ideal and negative ideal solution have been determined from the expression (8) as follows:

$$A^* = \{0,2852; 0,0120; 0,0171; 0,0239; 0,0357; 0,0107; 0,0100; 0,0050\}$$

$$A^- = \{0,0337; 0,0067; 0,0114; 0,0650; 0,1450; 0,0170; 0,0140; 0,0080\}$$

4./5. The separation measures and relative closeness of the particular alternatives to the ideal solution have been computed by using of the expressions (9) and (10), respectively, as follows:

| $A_i$ | $S_i^*$ | $S_i^-$ | $C_i^*$ |
|---|---|---|---|
| 1 | 0,2607 | 0,1690 | 0,16900 |
| 2 | 0,0458 | 0,2678 | 0,8540 |
| 3 | 0,1751 | 0,1360 | 0,4372 |
| 4 | 0,2156 | 0,0734 | 0,2530 |
| 5 | 0,2525 | 0,0980 | 0,2820 |
| 6 | 0,0741 | 0,2199 | 0,7480 |
| 7 | 0,1902 | 0,0983 | 0,3641 |
| 8 | 0,1690 | 0,1110 | 0,3960 |

6. On the basis of the values of $C_i^*$ the particular alternatives have been ranked in preference order as follows:

$A_2$(Paris), $A_6$(London), $A_3$(Frankfurt), $A_8$(Madrid), $A_7$(Milan), $A_5$(Amsterdam), $A_4$(Dusseldorf), $A_1$(Brussels).

As it can be observed, Paris has emerged to be the preferable alternative due to the following facts: the airport where the hub would be located, (CDG) has possessed the highest potential expressed by the population and per capita income to generate air travel demand. The influence of the another important airport near Paris (Orly) has not been considered. Furthermore, the airport CDG has possessed the other advantages like a low level of dominance of the incumbent airline and low cost of organising of the new 'hub-and-spoke' network (It should be noted that when demand on the particular routes has been constant the airline operating cost to satisfy it has been lower. The modest average cost per service of a single user while being on the airport has also shown to be an attractive attribute. The availability of only two airport ground access modes, a relatively high

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generalised cost of the cheapest mode and relatively low spare capacity have shown to be the main disadvantages of the location, but of less importance this time.

The evaluation of location of a new hub by use of single criterion approach like, for example 'minimum location cost' or 'maximum potential profit', etc., has provided different outcomes. Table 3 has been synthesised to compare the outcomes obtained by the application of different methodologies.

Evidently, the outcomes have significantly varied across the evaluation methodologies applying different attributes (criteria). This fact may be considered as the main reason why all results should be considered and judged with a high caution and exclusively after the appropriate modifications of both the alternatives and criteria carried out by the airlines themselves. These modifications could be realised by consideration of an additional set of attributes (criteria) as well as by using of the judgements of the airline experts in dealing

*Table 3: The outcomes of different methodologies - the airport ranking*

| Alternative/ Airport | Methodology | | | | |
|---|---|---|---|---|---|
| | Minimum cost[1] | Multiple Criteria[1] | Maximum profits[2] | | |
| | | | BR | PT1 | PT2 |
| Brussels | 1 | 8 | 4 | 4 | 4 |
| Paris | 2 | 1 | 5 | 5 | 5 |
| Frankfurt | 3 | 3 | - | - | - |
| Dusseldorf | 6 | 7 | 3 | 2 | 1 |
| Amsterdam | 4 | 6 | 1 | 1 | 1 |
| London | 5 | 2 | - | - | - |
| Milan | 7 | 5 | - | - | - |
| Madrid | 8 | 4 | - | - | - |

[1]The author's outcome; [2] The outcome of Berechman and de Wit (1996) (BR-Base Run; PT1-Policy Test 1; PT2-Policy Test 2)

with the weights of particular criteria. The proposed entropy method has allowed efficient inclusion of the experts' judgements into the evaluation procedure. Then, the modified weights can be applied in the TOPSIS method. Anyway, the proposed approach has emerged to be a useful 'tool' for an initial choice of the candidate airports for new airline hub.

## 6 CONCLUSIONS

The paper has described the methodology for multi-attribute choice of the location of new hub for an Westeuropean airline. The choice of new hub has become actual part of the airline business policy just after completion of the liberalisation of the European aviation market in April 1997. In choosing of the location of new hub the airline has been assumed to take into account different criteria. Nevertheless, the most important criteria have emerged to be the airport power to generate sufficient demand, market barriers represented by the 'strength' of dominance of the incumbent airline, the total cost of operating the new hub-and-spoke network, physical barriers represented by the limits of the airport capacity, the charge of the airport services, and the characteristics of the airport ground access nodes.

In order to illustrate how this problem could be easier resolved the Multiple Attribute Decision Making methodology has been proposed. This has included the definition of the set of alternatives (the airports that may be considered as the potential location of new hub) and assignment of the attributes (criteria) to each of them. Particularly, the cost of operating new hub-and-spoke network has been estimated for given traffic scenarios. Due to lacking of data related to the expert judgements, the entropy method has been applied to estimate the weights of the particular criteria. Then, the TOPSIS method has been chosen for determination of the optimal hub location as the convenient method.

The outcomes obtained from the application of the methodology have indicated that the airport Paris (CDG) has emerged as the preferable hub location for a 'peripheral' The airports Heathrow (London), Frankfurt and Barajas (Madrid) have accompanied him. The other airports have seemed to be less attractive for location of the new hub with respect to given set of attributes (criteria).

Comparison of different studies has uncovered the existence of a high sensitivity of the outcomes in dependence on the changes of the evaluation methodology and attributes (criteria). This implies that any methodology should be considered with caution and strongly in dependence on the purpose. Furthermore, some open problems concerning later development of the networks of the EU airlines as well as the field for the future research have still remained. One of them has been the problem of 'optimal' choice of the two or more hub locations in the network. This problem has already emerged at the most of the US airlines which have established the networks with two and three hubs.

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# Austin Bergstrom Airport Traffic Control Tower
## Establishment of a Major Activity Level Tower

*53 - 09*
*(handwritten)*

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# 1 BACKGROUND PROJECT JUSTIFICATION

Robert Mueller Airport has served the City of Austin, Texas, USA, since the 1930's. The surrounding area is completely developed, leaving the City unable to purchase land needed to expand runway capacity for long-term aviation demand. Voter referendums November 3, 1987 and May 1, 1993 confirmed the decision to develop a new commercial airport. Numerous studies identified the active Bergstrom Air Force Base as the preferred site.

Options of joint military-civilian use of the Air Force Base were explored but no agreement could be reached. In July 1991, a United States Congressional commission formally recommended that the base be closed. On August 1, 1991, the Austin City Council passed a resolution formally designating Bergstrom as the preferred site for a new commercial airport. Located 7 miles southeast of the Austin central business district but within the city limits, the site is surrounded by predominantly undeveloped land. This paper covers the process utilized to convert a military facility to a commercial airport.

The control tower project had to be submitted on fiscal year planning budgets and assigned a Congressional budget line item number. The budget line item number is used for the annual budget submittal to the United States (U.S.) Congress. Projects are prioritized and funded as monies are available. A project might go through the annual budget process as many as five times before being discarded or funded. Documentation of the problems and justification for the proposed action had to be submitted to Washington, D.C. and prioritized with other projects from across the United States of America. The City of Austin, Texas, made a commitment to provide portions of the funding to balance the federal government investment.

After the project successfully maneuvered this process, project authorization was given by Congress and monies assigned to the project. The Federal Aviation Administration's (FAA) Southwest Regional Office staff was given the assignment to proceed. The FAA Airport Development Office, Airports Division provided grant funding to the City of Austin for portions of the sponsor improvements. The Airway Facilities Division managed the airport facility projects built by the FAA, including the Airport Traffic Control Tower.

Austin Bergstrom International Airport is the only new major activity airport under construction in the United States at this time.


# 2 SITING STUDY FOR TOWER LOCATION

The first step in establishing a new tower is to conduct a site study to determine the best location for the airport traffic control tower (ATCT). Although there is an existing United States Air Force ATCT, it is not adequate for the management and control of a commercial airport. The military tower does not provide adequate operational/equipment space. The cab is not large enough for all of the equipment used by the FAA, the military and the sponsor for cargo and commercial carrier operations. In addition, the tower is not tall enough for the projected airport expansion and the continued line of sight requirements. Also, a co-facility would require relocation of the existing municipal facilities to the new airport.

The Airport Layout Plan (ALP) (See Figure 1.) for the new airport indicated an airfield configuration that included the existing 12,250-foot Runway 17R/35L and a new 9,000-foot runway located 6,700 feet to the east designated R/W 17L/35R. The widely spaced parallel runways equipped with instrument landing system (ILS) and approach lights will allow dual instrument operations in poor weather conditions. Three of the approaches are Category II while a third is Category III (near zero visibility conditions). Each runway is planned to have associated high speed exit ramps, taxiway exits, and parallel taxiways for access. The two runways are planned to be connected by a pair of east-west cross field taxiways located south of the terminal area.

At the beginning of the site study, the airport plan included a 336,000 square foot terminal building with a Frontal (Contact) Gate/Atrium concept; an air cargo facility at the northeast of the existing runway; a general aviation T-hanger on the west side of 17L/35R south of the cross field taxiway; and the State aircraft pooling board west of the Runway 35R approach. South of the general aviation facility; the Texas Army National Guard would be in an undetermined location; and future airline maintenance area would be located east of Runway 35L approach end and the existing ATCT.

The basis for the Site Analysis is Federal Aviation Administration (FAA) Order 6480.4. This order includes mandatory requirements and non-mandatory requirements when conducting ATCT site and height selection.

The mandatory requirements include:

1. Visibility of airborne traffic (primary consideration) with clear, unobstructed direct view of the approach to the end of the primary instrument runway and all other active runways and landing areas;
2. Complete visibility of airport surface areas utilized for the movement of aircraft which are under the control of the ATCT;
3. The plot site shall be sufficient to accommodate the initial building and planned future expansions;
4. The tower must not obstruct Navigable Airspace in accordance with Federal Aviation Regulations (FAR), Part 77.

The non-mandatory requirements include:

1. Tower be located and oriented to provide depth perception of all surface areas;
2. Tower cab orientation shall face north or alternately east, south or west in order of preference, avoiding rising or setting sun;
3. Visibility from the tower should not be impaired by direct or indirect external light sources;
4. Ground operations of aircraft and airport ground vehicles should be visible from the tower;
5. Consideration of local weather, fog or ground haze;
6. Avoid high noise levels;
7. Access to the site should avoid crossing areas of aircraft operations; and
8. Avoid areas with jet exhaust, fumes, industrial smoke, and dust.

FIGURE 1

ILS/ALS SHELTER

ASR-9

EAST RUNWAY

ONION CREEK

BURLESON ROAD

ILS/ALS SHELTER

WEST RUNWAY

RTR "1"

ATCT

TERMINAL

U. S. HIGHWAY 183

RTR "2"

ILS/ALS SHELTER

RTR "3"

ILS/ALS SHELTER

STATE HIGHWAY 171

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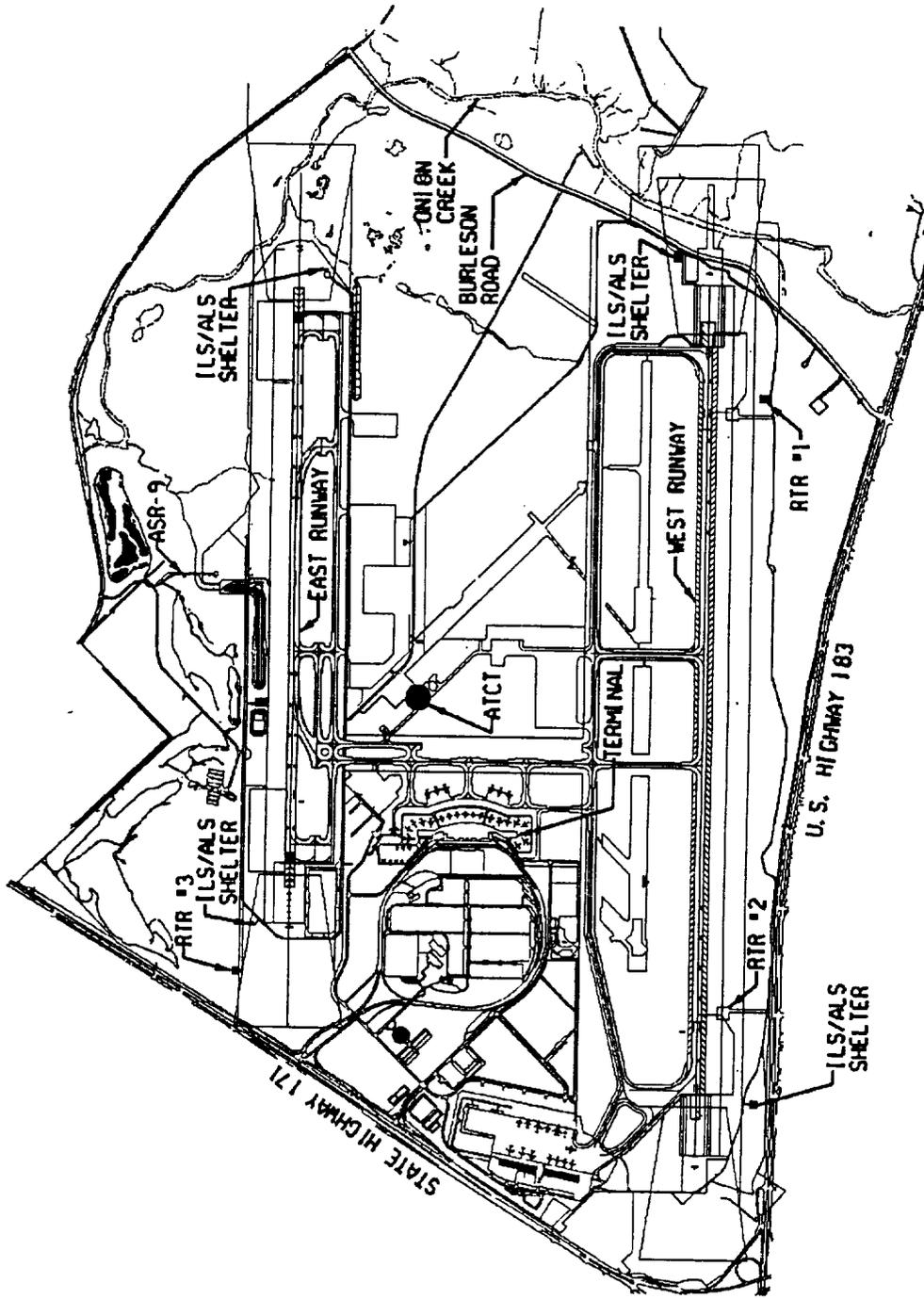
Four alternative sites with two heights (185-foot and 209-foot eye level) were evaluated using a weighted matrix based on the siting criteria. The siting study was prepared by FAA staff engineer, Marco A. Molinar, P.E.

Shadow studies were developed for all site alternatives. The shadow study depicts the location of buildings, runways, taxiways, proposed ATCT sites and the line of sight shadows. Also included are areas of future development and shadows associated with these future facilities. Shadows crossing runways, taxiways, and intersections with the apron area should be avoided and are used as a basis for disqualifying a site. After carefully weighing all factors, the location designated as Site 2 (See Figure 2) with a cab floor elevation of 199 feet was recommended for the establishment of the new Major Activity ATCT.

The recommended site is submitted on FAA Form 7460-1, Notice of Proposed Construction or Alteration for airspace review and compliance with FAR 77. The review requires latitude and longitude of the facility, ground elevation above Mean Sea Level (MSL), structure height, overall elevation, closest distance of structure to a runway, frequency and peak power output of any transmitter equipment, site plan and an obstruction chart, if available. Coordinates are based on United States Geographic Survey, North American Datum - 1983 (NAD 83).

The site selection recommendation was evaluated by the FAA Site Selection committee. The committee is composed of representatives from Airway Facilities, Air Traffic Division, Security, Air traffic controllers, the National Air Traffic Controller Association (NATCA, the controllers union), real estate office and staff from the facility area. The selected site is then requested from the airport sponsor. Once a site is approved, the project proceeds into the design phase.

## 3    COORDINAITON

The FAA Southwest Region (SW) does have guidelines for coordination in Order SW 6011.2C, Coordination of Approved F&E Projects. Coordination issues for this project were far reaching. From the FAA operational staff, air traffic controllers and NATCA to the City of Austin officials to the project overview personnel from Washington, D.C., coordination was a key element in the progress and success of this project.

### 3.1    Internal FAA

The chosen site had to coordinate and sequence with other FAA facilities and systems that would interface with the control tower. These facilities included three Radio Transmitter Receiver (RTR) sites, an Airport Surveillance Radar (ASR9), Instrument landing systems (ILS) for all four planned approaches, and approach lighting systems such as the three Medium Intensity Approach Lighting Systems with Runway Alignment Indicating (MALSR) for the Category II approaches and a variable intensity approach lighting system for the Category III approach.

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The FAA Team was composed of representatives of many divisions and included regional and area field staff. Personnel from Airway Facilities came in the form of Regional Program
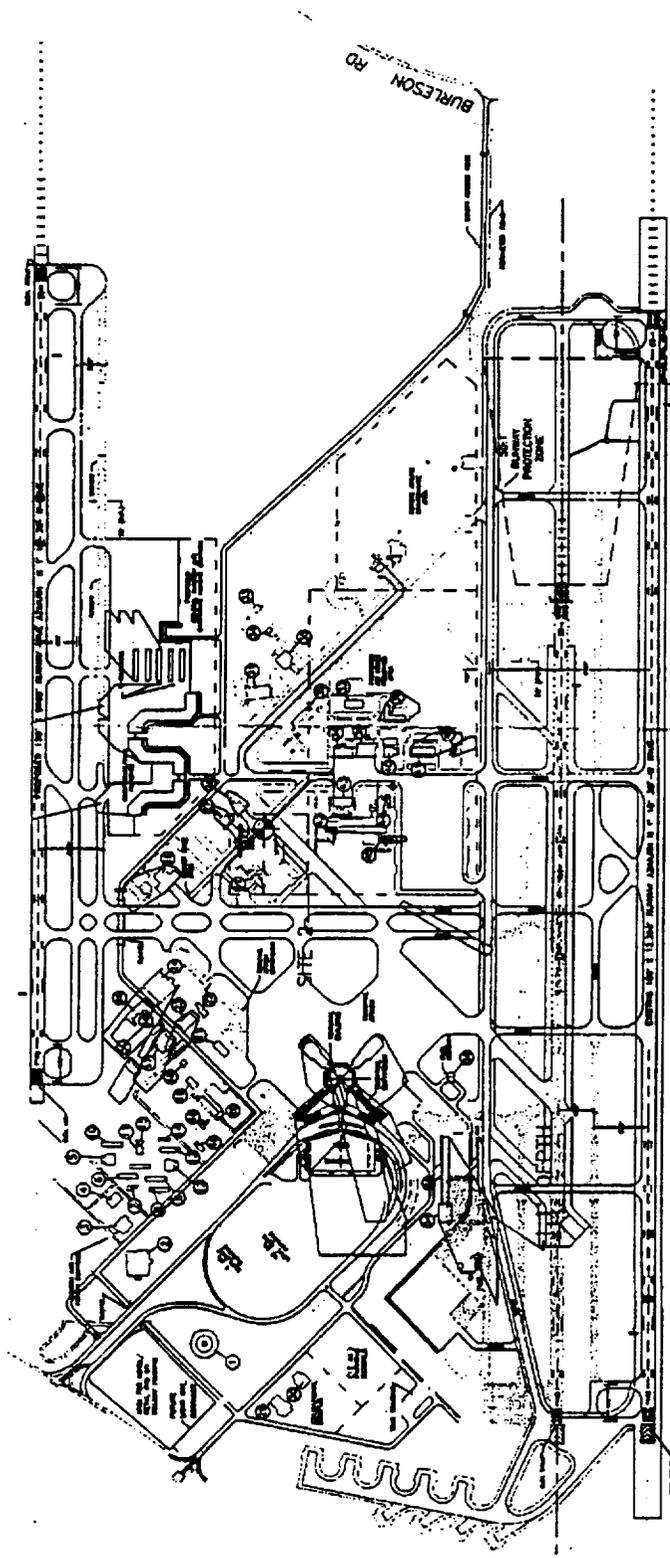
Managers (RAPM), staff engineers, project managers and lead engineers, system specialists in the field and regional office; Air Traffic in the form of a regional representative, the existing facility manager, air traffic controllers and union representatives. Security, real estate, telecommunications, contracts, legal and procurement were also included in the project and the review process. (See figure 3.)



ADO - Airports Development Office
SMO - Sector management Office
RAPM - Regional Associate Program Manager
PA - Project Authroization
NATCA - Nationa Air Traffic Controllers Association
PASS - Professional Airway System Specialist
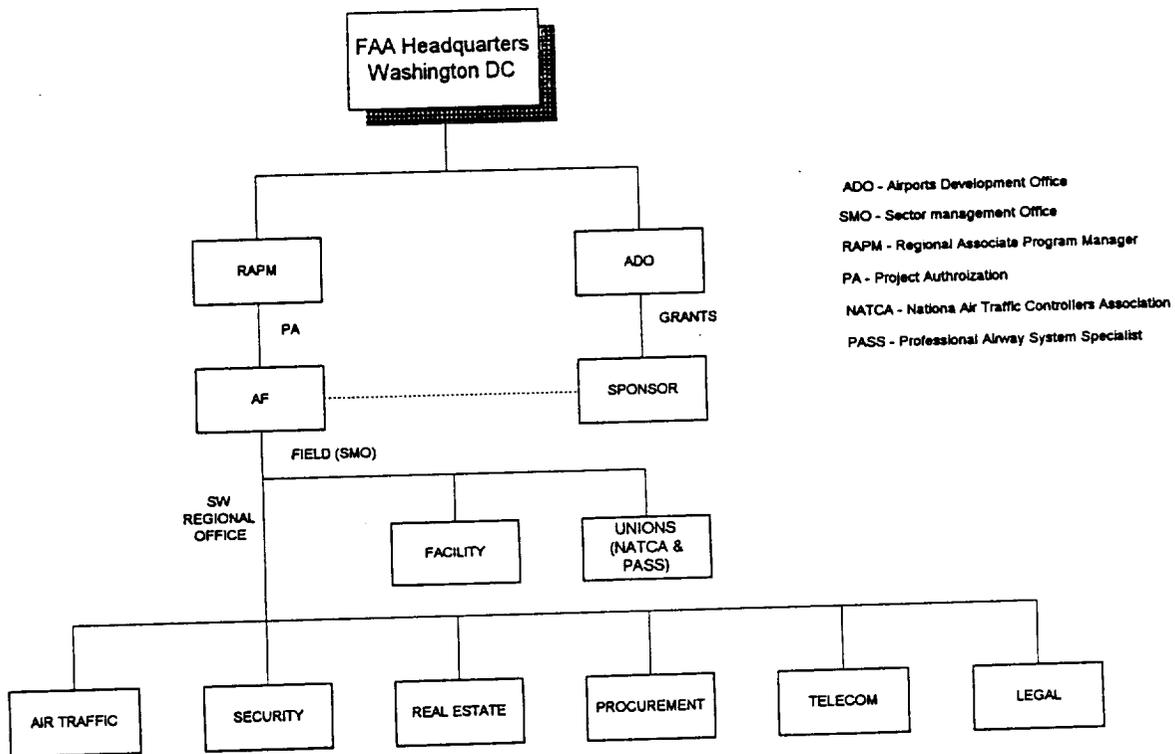
Figure 3

## 3.2   City of Austin

Initial contact was with the New Austin Airport Team, an extension of the downtown City officials. As the magnitude of the project was understood, building code officials, real estate, and legal representative became more involved. The FAA makes every attempt to comply with the Uniform Building Code (UBC) or Southern Building Code (SBC) as applicable, the Americans with Disabilities Act (ADA) and local codes that are more stringent than FAA requirements. An ATCT structure is very specialized with limited access. Application of City codes to FAA facilities can be limited by FAA's sovereign immunity under U.S Public Law 100-678 to what the Federal government feels is "appropriate and beneficial". . Working with the City of Austin, every attempt was made to comply with their local codes. The City was also included in the 50% and 90% design reviews. One point of disagreement concerned the single means of egress from the ATCT cab. Per an agreement with the Occupational Safety and Health Agency (OSHA), the FAA automatically provides a dedicated stairwell that is pressurized, ventilated and protected by fire sprinklers.

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Working with the New Airport Team at the site, the joint effort coordinated the construction schedules, architectural types, joint use facilities and sequencing of the construction.

## 3.3    United States Air Force

At the beginning of the design phase, the United States Air Force (USAF) was still expected to be involved at the airport through the U.S. Air National Guard Unit. Due to the base closure, an extensive environmental survey had been done to the site and environmental problems were identified to the City, who then worked with the USAF to eliminate them. The USAF presence also restricted the area available to the FAA for the ATCT site. The ATCT site was surrounded by a cantonment area with very restrictive access limitations. Eventually the Air National Guard unit was reassigned elsewhere and the FAA acquired more area for expansion as well as an improved routing for the control cable loop systems required for interface to all on site navigational aids.

## 4.    DESIGN PHASE

## 4.1    Site Consideration

### 4.1.1    Site Access

As a matter of security, the FAA wants to limit or at least control access to ATCT sites. Since the Oklahoma City bombing, security has increased for this key element of the National Airspace System (NAS). Due to the location of the site, limiting access was not as great an issue as staying off active airspace areas while respecting the USAF area restrictions. The South Access Road built by the City of Austin provides major access to the finished site. The access was limited on the east side of the site by the USAF. After coordinating with the City and Air Force, a road alignment was agreed upon. IV-A.2. Utilities

Early coordination with the City of Austin allowed for the needs of the ATCT to be incorporated in the City's utility corridor design. Power, water, and natural gas demands were accommodated and a mutually agreeable point of connection was established near the edge of the ATCT plot. The early coordination allowed for inclusion of empty conduits in the City utility corridor design for future use by the FAA for the fiber optic loop cable system used to monitor and control all the navigational aids.

Telecommunications were also handled in a slightly different manner. The City decided to have their own telecommunications system on the Airport. This entailed several  private branch exchanges and points of demarcation with Southwestern Bell (SWB) at the edge of the Airport property. This posed a difficulty for the ATCT being located in the middle of the Airport.

For the purposes of safety, robustness, and security the FAA, requires direct connection with SWB. As a result, arrangements were made for SWB lines to come through the City duct bank system to the FAA facility

## 4.1.2    Environmental Site Assessment

In response to Environmental Quality Regulations and implementation of the National Environmental Policy Act (NEPA), FAA established Order 1050.1E, Policies and Procedures for Considering Environmental Impacts. An environmental assessment (EA) is a document describing the environmental impact of a proposed action and its alternatives. One alternative is always to do nothing. The FAA does define some categorical exclusions from this process in Order 1050.1E and also in FAA Order 5050.4A, Airport Environmental Handbook. An ATCT is not excluded. If it is concluded the action is not a major impact significantly affecting the quality of the human environment, the responsible official shall prepare and file a Finding of No Significant Impact (FONSI).

In the case of the Austin ATCT, the Environmental Assessment was conducted. This study investigated environmental consequences such as air and water quality, land use, floodplains, biotic communities (wetlands), cultural resources, hazardous and solid waste, fuel storage, pollution prevention, socioeconomics, utilities, light emissions and cumulative impacts. Since the site had been selected based on FAA siting criteria and other site eliminated, the alternatives studied were the proposed action of building the tower at the selected site or take no-action.

The construction activities would temporarily alter the environment with dust and equipment emissions. To control the potential pollution, the contractor was specified to follow FAA Advisory Circular 150/5370-10A, Standards for Specifying Construction of Airports, Item P-156, Temporary Air and Water Pollution, Soil Erosion and Siltation Control. If the total disturbed area is greater than five acres, a notice of intent under a general NPDES storm water permit is required.

The main operational change at the ATCT that would affect the air quality is the installation of a 350-kilowatt engine/generator set for backup power. Due to the 2,000 gallon above ground fuel storage tank (AST), a spill prevention, control and countermeasure plan will be required and the tank must be registered with the Texas Natural Resources Conservation Commission (TRNCC).

The study found that no significant environmental impacts (FONSI) would result from the construction of this ATCT facility.

## 4.1.3    Environmental Due Diligence Audit (EDDA)

To establish FAA policy, procedures and responsibilities in the acquisition and disposal of real property (real estate), FAA Order 1050.19, Environmental Due Diligence Audits in the Conduct of the FAA Real Property Transactions was issued in August 1994. An EDDA may be required for purchase or lease of real estate and the process is broken into three phases. The purpose of a Phase I EDDA is to determine the likelihood of environmental

contamination at a property to be purchased, leased, sold or otherwise transferred. If contamination is suspected, the process continues to Phase II to confirm (by on-site testing and laboratory analysis), whether property under consideration for acquisition or disposal is contaminated. If the sampling and analysis performed during Phase Two reveal the presence of hazardous contamination, the FAA must decide whether to find another site or to perform a risk assessment for remediation. This process is closely aligned to the standard practice described in American Society for Testing and Materials (ASTM) designation E 1528-93 and E 1527-93. If the FAA and the airport sponsor were agreeable to a "hold harmless" clause, the FAA could consider not conducting an EDDA. In the case of Austin Bergstrom Airport, prior knowledge of the site, usage and the property ownership agreement dictated the FAA conduct an EDDA.

The Phase I study identifies prior ownership and land use. Site inspection seeks to document the condition of the grounds, buildings, and the presence of fuel storage tanks, PCB-containing equipment or asbestos. Federal, state and local records are reviewed for potential contamination sources. Neighboring properties are checked for use and potential contamination. The generation, storage and disposal practices of hazardous materials at the site are investigated. The site is reviewed for the presence of sensitive environmental areas such as wetlands, historic value or recreational land use.

The phase I EDDA identified potential environmental conditions. Drainage from the surrounding areas flow onto the site. This flow crossed fueling activities and airport ground equipment (AGE) maintenance using petroleum products and solvents. An area on the site indicated vegetative stress. A Phase II assessment was recommended.

The Phase II began with determining likely sources of contamination. Sampling of soil, groundwater and surface water identified the problems. The site included a septic tank and drain field, a drainage ditch from AGE maintenance facility, and an area of stressed vegetation. Soil analysis indicated the presence of barium, cadmium, chromium, lead and silver. The groundwater samples indicated barium in all three monitoring wells.

The conclusion of the study was for the FAA take steps to avoid liability associated with the cadmium and lead detected above background concentrations. The FAA notified the City of Austin. The City of Austin prevailed upon the USAF to clean these items

### 4.1.4    Staff Acceptance

The FAA plans at the new ATCT facility consolidated the location and efforts of the Air Traffic
Field staff (air traffic controllers) and Airway Facilities field staff (system maintenance). After determining projected staffing needs, the FAA determined the staff would be co-located at the ATCT base building. Each staff section has a unique function and space requirements. It was necessary to take this into consideration when designing the base building. Since both groups are represented by unions, the design staff was required to keep the unions informed and involved. This was accomplished by holding numerous coordination meetings for the base building layout. Considerations included means of ingress and egress, parking, provisions for an expandable meeting room, adequate storage and air controller locker location. The final floor layout was defined and refined between

the 20 and 50% review. After the 50% review, the floor plan and space allocations were fixed.

After coordination with the City of Austin for exterior architectural finishes, sample boards of every architectural finish for two decorating scenarios were sent to the Austin field facility and the field staff decided which palette to use. The selections were incorporated into the 90% design review submittal.

## 4.2    Unique Features

### 4.2.1    Structural

Special considerations have to be given to facilities of all types built in the south central part of the United States, especially the Central Texas area. The surface soil is a black clay with little sand or organic material content. The result is a very expansive, and unforgiving, soil. Soil heaves between wet and dry times can be in excess of 10 cm. The expansiveness of the soil and the depth to bed rock (or stable soil) can vary significantly from location to location. As a result, soils testing at the location of each and every building is important.

The typical foundation for this type of a tall thin tower in this part of Texas would be a mat foundation with piers down to stable soil or bed rock. The mat foundation is provided to offset the righting moment and the piers to support the weight of the building and mat.

In this particular instance, it was found that the uplift of the soil to be extremely significant. The maximum potential vertical rise for the soil in the area of the ATCT was approximately 10cm. As a result, the foundation design was different than any Airport Traffic Control Tower built in the five states of the FAA Southwest Region. The uplift was found to be so great that piers were not needed. This foundation needed only an oversized mat.

### 4.2.2    Architectural

As we have already discussed, in the building of a new airport, coordination with all of the associated agencies is important. One of the areas of consideration is the architectural aspect of the facilities. This is especially important were the facility will; be in plain view to millions of people every year from the passenger terminal building.

Typically, the FAA has prepared standard tower and base building designs at the national level. These designs are then site adapted by the local Architect and Engineering firm for the specific soil and weather conditions.

In our case, since the base building was being designed from the ground up, we took that approach that it should also be architecturally pleasing and match the architectural flavor of other facilities being designed for the airport by other firms. It was decided to follow the general lead of the passenger terminal design as this was the main architectural feature that the public would see and identify with.

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The basis of the design was "New and Old". The "New" aspect was accomplished by using dull faced aluminum while the "Old" aspect was provided by materials that mimic the naturally occurring limestone deposits in the region. It is felt that this combination is both aesthetically pleasing and will continue to be so for many years to come.

When such modifications are made to tried and proven facility concepts, precautions have to be made to ensure there is no degradation in the overall usability of the facility. In our case, sound was a significant design consideration, especially since the facility was being located within the Aircraft Operating Area and would be subject to significant levels of outside noise.

The FAA national standard design entailed plain 10cm thick pre-cast concrete panels with interior firred out stud walls with thermal insulation. The acoustical transmission coefficient for this wall was 60. To get the "New" effect, however, an external aluminum skin was used for the base building. Special attention was paid to ensure the acoustical transmission coefficient was at least as good as 60. The resulting design actually increased the sound deadening characteristics by decreasing the sound transmission coefficient to 56.

The character of the New/Old was also carried inside the building. The main entry of the facility incorporates black slate, rough textured limestone colored block walls, and open wood beam ceilings which are then offset by stainless steel trim and special high efficiency sky lights.

Relationships to other facilities within the Austin area played a significant role in the final size and layout of the Base and Environmental Support Buildings. FAA standard designs take into account typical facilities. However, the new Airport Traffic Control Tower facility was to become an area Terminal Radar Approach Control (TRACON) facility and the center for the administration and maintenance of all area air traffic facilities. As a result, the number of air traffic and airway facility personnel to be housed and their administrative and maintenance areas had to be accounted for.

The resulting Base Building was ultimately broken into functional areas. Relationships between offices, technical considerations for electronics, and building codes played a major role in the final layout. Additional offices for airfield maintenance personnel, work rooms, maintenance bays, and the standby engine generator and chiller plants were removed to the Environmental Support Unit building adjacent to the Base Building.


### 4.2.3   Site Access

The location and accessibility of a critical air traffic control facility is always of major concern. The site must be easily accessible by the day to day employees, especially for a larger facility with many work shift changes. But it must also be secure from hostile terrorist activity or mischievous vandalism.

At the onset, the chosen site for this facility was one of the best sites for security but lacked clear and easy access. The site was located in the middle of the Texas Air Nation Guard's (TXANG) allocated cantonment area which also happened to be an active aircraft operating area. With the agreement of the TXANG and through coordination with the City of Austin,

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a narrow "no man's land" was established through a portion of the cantonment area to gain access for utilities and site personnel.

Ultimately, the TXANG group stationed at the Base was consolidated with another TXANG group and relocated to an active Air Force Base. With this, the aircraft operations in this area became non-existent. This left the facility with the best in security, safety, and accessibility.

## 4.3   Quality control procedures

In the past, the FAA regional staff designed a project to the 90% level before having a review meeting with the field and area personnel. This 90% review meeting is called a Phase I meeting. While this approach works well enough for smaller, low conflict facilities, it does not work for larger projects such as the Radar Tower (ASR9) and ATCT.

As communications have changed and personnel have become more involved in processes that affect their workplace, the Phase I review at 90% design for other facilities was generating fundamental changes that altered the basic approach to the project. The addition of a 50% review with area and field staff helped avert changes of that magnitude. Due to the size and complexity of this tower project with base building, the initial review began at 20% with the base building layout and orientation of the tower cab. Once the basic orientations and fundamental layouts were established at this phase, design could proceed full bore with minimal concept changes.

The objective for the 50% review is to verify site data, coordination of utilities, inclusion of field and area staff review comments and to identify any needed changes. Review packages of plans and specifications are sent out and approximately two weeks of review time allowed. Standardized review/comment sheets are also sent. The project manager asked for the comments to be sent in to the project engineer two days before the meeting. The review comments are compiled and sent to the design and review engineers. This allows time to provide a response, which can be aired at the review meeting. During the review meeting, all comments are reviewed and concurrence and action items identified. These comments are incorporated into the next design phase and used at the next review to confirm they were resolved.

The 90% review is conducted in the same manner as the 50% review and is intended as a review for completeness and compliance and to consolidate the design which is now basically complete.

The 99% review is a last clean-up before final documents are issued. The review comments from the 90% meeting are used to verify all changes have been made. After this the final contract documents of plans and specification will be sealed by the licensed professional engineers and then printed and sent to the contracting officer for the procurement phase.

The FAA Procurement process is conducted by a contracting officer. The project is advertised for construction contractors to bid. On projects the magnitude of an ATCT, a pre-bid conference is held, usually at the project site to allow visual inspection of the site by prospective contractors. This conference allows the perspective bidders to ask questions,

point out conflicts and to view the site. These pre-bid conference comments are compiled and sent to all bid document holders. If modifications are required, they will be made by addendum to the construction documents. The deadline for submitting a bid is strictly enforced. The contracting officer opens the bids, tabulates them and compares the low bidder to the government cost estimate. The qualified low bidder is examined for financial stability, a good working record and adherence with insurance requirements. The government cost estimate for this project was $9,096,201. The selected contractor was Spaw-Glass of San Antonio, Texas with a bid of $9,027,000.


## 5      PLANTS CONSTRUCTION AND PRESENT STATUS

If validated, the construction contractor is given a Notice of Award. When paper work has been submitted, the contractor is given a Notice to Proceed (NTP) and a timeframe in which he must begin the construction. The NTP is usually presented at a pre-construction where the contracting officer validates paperwork and the contractor's understanding of government construction management procedures. The contractor would be introduced to the field staff and the FAA resident engineer (RE). The RE is the key point of contact between the contractor and the regional staff and engineers. The pre-construction conference took place October 19, 1995.

Groundbreaking for the Austin Bergstrom ATCT facility took place in May, 1996. With respect for tradition, a Christmas tree was mounted on the top of the tower when the structure was "topped out", November, 1996. The plant portion of the construction was completed as of October, 1997. The contract acceptance inspection took place September 30, 1997. The certificate of beneficial occupancy was achieved on October 31, 1997. A tall tower grounding effort commenced August, 1997, and was completed November, 1997. The electronics installation began September, 1997, and should be complete by September, 1998. FAA Administrator Jane Garvey visited the site August 27, 1997. The tower is to be complete and ready for commissioning by October 1998. The Austin Bergstrom Airport began air cargo operations July, 1997, and is scheduled to begin commercial operations in May 1999.

The construction contractor, SpawGlass of San Antonio, Texas, USA has won several awards for this project. In October 1997 the Central Texas Chapter of Associated Builders and Contractors presented SpawGlass the Excellence in Construction Award. This qualified SpawGlass to enter the Associated Builders & Contractors National competition where they won a National Merit Award for Public Works Construction.

# REFERENCES

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# A STUDY TO OPTIMISE THE ENVIRONMENTAL CAPACITY OF AMSTERDAM AIRPORT SCHIPHOL

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## 1. Context

The last five years Amsterdam Airport has experienced an extremely high growth. However this growth can be attributed only partly to the growth of the airline market itself. The economic growth of the Netherlands and the Western European region has been moderate in the period 1992-1995. Only 1996 and 1997 have shown some economic recovery, at least in the Netherlands. A factor that certainly has contributed to airline market growth concerns the air fares, which have dropped considerably, especially through the introduction of new promotional fares. But even taking the fares into consideration, the contribution of market growth to Schiphol's growth is moderate. The main factor has been the market share of KLM and its partners. A number of factors can be mentioned in this context. During the first half of the 90's KLM has extended the co-operation with Northwest Airlines, mainly by codesharing on the North Atlantic route, and by offering through connections in the USA by the Northwest-network, and in Europe by the KLM-network. An important year was 1992, when the Netherlands - as the first European state - signed an *Open Skies* Agreement with the United States. In this agreement an *anti-trust immunity* for KLM/Northwest was included which made it possible to closely integrate both airline networks. This stimulated traffic at Schiphol further. Also during that period KLM started to build up a new *wave system* at Schiphol, by concentrating European arrivals and departures (in addition to the European and intercontinental) in such a way that connectivity via Schiphol improved considerably, which mainly boosted the connecting traffic via Schiphol. A summary of this growth may be found in next table:

| TABLE 1: Traffic volume at Amsterdam Airport Schiphol, 1992 - 1997 | | | | | | |
|---|---|---|---|---|---|---|
| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| Passengers (mln) | 18.7 | 20.8 | 23.1 | 24.9 | 27.3 | 30.1 |
| Cargo (000 tons) | 695 | 775 | 838 | 977 | 1083 | 1159 |
| Movements (000) | 238 | 260 | 274 | 291 | 322 | 350 |

Although KLM's strategy has always focused on a bigger market share as a partner in one of the few remaining *global networks*, the resulting growth of this strategy has surprised policymakers, especially from the point of view of environmental protection. In 1995 it was agreed that the development of Schiphol would be subject to environmental constraints. An important element in these constraints are the *noise contours*. According to these constraints a maximum of 15.000 houses within these contours are allowed to be affected by a certain noise level until 2003. After 2003, when the fifth runway is expected to be operational, this contour must shrink even to 10.000 houses. The fast growth however has led to a situation, that within these noise limits, after 1997 only a limited traffic growth is possible. Certainly if traffic demand is continuing to increase fast, drastic measures are needed to obey the noise limit. Measures are already in operation, but their effect is apparently not sufficient enough. Chapter 2- aircraft have already disappeared almost completely, although this was only supposed to be effective by as long as 2002. The airport has discouraged night operations by differentiating landing fees in certain periods of the day. And finally the air transport policy is - when granting access to Schiphol - taking into consideration also the noise performance of the aircraft that is going to be used, when using Schiphol. Nevertheless, some of the measures only become effective after a certain period, and their effectivity is still limited for the short term.

During the second half of 1997 it became clear that - despite of the measures that have already been taken - the noise limit would be violated. It has led to a situation that from April 1st, 1998 Schiphol is *fully slot-coordinated.* Moreover it was agreed that from 1998 onwards, 20.000 extra slots will be granted annually, enabling a further growth from 360.000 movements in 1997 to 460.000 movements in 2002. Comparing this to the actual market demand, which - for 1998 - which had been estimated already at a level of 420.000 movements, this slot-coordination means a severe restriction. It also implies economic damage not only for the airlines, but possibly also for the surrounding regions. The economic damage will certainly emerge when restrictions continue over the longer term. This situation at Schiphol is however quite unique. Not by the implementation of the slot co-ordination, which is existing already at several European airports. But the fact that the co-ordination has been implemented because of environmental reasons, and not because of an operational capacity constraint, like runway capacity. Estimations of long term runway capacity at Schiphol may for instance - depending on the assumptions of peak patterns - increase to a level as high as 600.000 movements, indicating that the operational limits of the airport has not yet been reached.

These considerations have brought up the question, how to implement a mixture of policies, to minimise the economic damage of restricted traffic volumes, within the limits that have been set. The existing slot co-ordination has a strong regulatory orientation. The co-ordination committee is using strict operational rules, and *grandfather-rights* are an important element in using these rules. This may however not necessarily be efficient. It does not guarantee that the best economic performers are given access to Schiphol. It may even lead to a situation that the environmental improvement of the measures is low, but the economic damage is considerable. And even more important: *Incentives* to improve environmental performance are not inserted into the system. When these incentives are available, a situation may be created by policymakers, that environmental (noise) costs are internalised in the system, stimulating airlines to use the most noise friendly aircraft at the most noise friendly times of the day. It may even mean that the effect of these incentives would be a growth in 2002 beyond the limit of 460.000 movements, within the noise limits. A mixture of measures leading to this, would be considered as efficient, as it limits economic damage, but has a considerable environmental performance.

## 2. Unrestricted Scenarios

To address the effects of measures to be taken, it is necessary to separate and define a restricted situation versus an unrestricted situation. Within each of both situations different future growth patterns for Schiphol are assumed by introducing two alternative economic scenario's. One so-called 'cautious' scenario based on a moderate economic growth until 2003, including a stabilised market share for KLM. Another so-called 'favourable' scenario based on a more optimistic economic growth, combined with the assumption that KLM would gain further market share. This results in various combinations to contrast the differences in traffic development, e.g. two economic scenarios within an unrestricted situation for Schiphol airport as well as two economic scenarios for various restricted airport scenarios. (see figure below)

To trace the differences between the resulting alternatives an Integrated Model System has been developed by the Netherlands Civil Aviation Department (RLD). The two economic scenarios used in this model are based on two macro-economic mid term scenarios of the Dutch Central Planning Bureau (CPB). These scenarios describe the economic developments of the Dutch as well as the world economy until the end of the year 2002.
For both economic scenarios aviation industry scenarios are developed in case of unrestricted capacity on Schiphol airport. The full development of the KLM five waves system at Schiphol Airport fits in these scenarios.
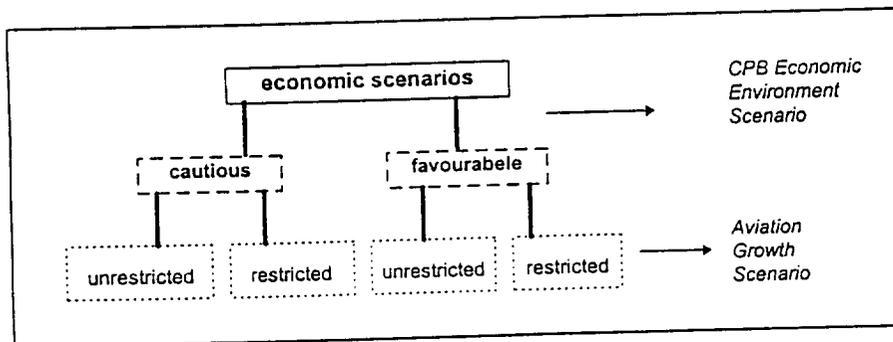


A continuation of the aeropolitical selectivity policy of the Dutch government is another assumption made in the aviation scenarios. This implicates that even in the unrestricted scenarios of the model an unbridled growth of aviation is excluded from the results.

For both unrestricted scenarios the following impacts are analysed or will be included in the Integrated Model System for the period until the year 2002 :

- traffic and transport on Schiphol; that is both the passengers- and freight volumes and the number of aircraft movements.
- environmental effects in the vicinity of Schiphol Airport; that is both the number of hindered houses and the surface of the so-called 35 Ke noise contour.
- the economic effects of increasing traffic volumes for the vicinity of Schiphol airport; that is the contribution to the local employment and the added value.
- later on monetary preferences of 'noise consumers' in the various noise zones around the airport will be included to study possible trade-off effects between positive economic effects and negative external effects in the different areas around the airport.

The corresponding traffic volumes for Schiphol are displayed in next table. These figures are generated by the *Schiphol Competition Model,* which will be discussed in more detail below.

| TABLE 2: Unrestricted Traffic Scenarios , 1996-2002 | | | |
|---|---|---|---|
| Year | 1996 | 2002 | |
| Scenario | | Cautious | Favourable |
| Pax (mln.) | 26.8 | 39.2 | 48.3 |
| Cargo (mln. ton) | 1114 | 1472 | 1766 |
| ACMs (1000) | 322 | 452 | 533 |

It is clear that the *favourable scenario,* may have far going implications for Schiphol. Not only with respect to the necessary airport extension like terminals, and the new runway, but particularly with respect to the *noise contours* that may - very likely - be exceeded in this scenario without additional measures. The necessity of these measures is probably much less in the *cautious scenario.* It may even mean - depending on the noise emissions - that no additional measures have to be taken as the volumes of 450.000 movements are just within the limits set by the slot-coordination.

## 3. The Schiphol Competition Model

Starting with 1996 volumes at Schiphol, the growth in passenger demand is forecasted by this model based on economic growth by world region, on trade, and on air fare levels. The demand elasticity's vary by region, and between business, independent leisure, and inclusive tour travel. Passenger demand GDP elasticity's vary between +0.6 (European destinations) and +2.0 (intercontinental destinations, southern hemisphere). These elasticity's are assumed to decrease in time. Fare elasticity's are -1.0 (leisure passengers) and, in addition, there is - ceteris paribus - an underlying annual traffic growth of up to 1% per annum.

This conventional approach is enhanced and extended to reflect on Schiphol's throughput the effects of competition from other airports. This will primarily affect transfer traffic, a particularly important segment at Schiphol where the O-D traffic is generated from a rather limited domestic market. A hierarchical logit model, calibrated on existing information for passengers' air route choices, is used to forecast how passengers choose between alternative air routes via competing airport hubs.

Unlike many air traffic forecasting systems, which assume unlimited airport capacity, the Schiphol Competition model is able to simulate and forecast the traffic volume consequences of a constrained capacity situation, arising from potential policy measures. This enables the model user to assess the impacts of these policies, compared to unconstrained forecasts. This provides a basis to both evaluate the impacts and the robustness of alternative government policies.

The model has been designed to address the following categories of policy measures to reduce airport throughput until 2002.

- quotas, or slot control, limit the number of aircraft movements and can be applied to particular traffic categories, for example a ban on night traffic; quotas can also be imposed on total passenger or cargovolumes, although the mechanism to achieve these political targets is less clear in practice;
- levies or landing surcharges may be applied uniformly or on specific aircraft types or groups of aircraft movements;

- passenger surcharges may be applied uniformly or on specific passenger market segments, although discrimination has to be avoided.

One of the policy instruments that directly affect passenger demand are the departing passenger taxes and passenger demand quota. The passenger tax is added to the airlines' fare and suppresses demand through the price elasticity. Where passenger demand is constrained to a policy target (a quotum), the model calculates a 'shadow tax' as the cost that would be required to constrain demand to meet the policy target. The underlying principle is that, when constraints are effective, the airlines intend to serve the highest yield passenger segments, and these are likely to be those with low price sensitivity and those with relatively limited choice for alternative routes for the journey. The shadow tax gradually reduces the most price sensitive passenger segments (leisure passengers and those with alternative routes like transfer passengers, or those having access to high speed rail services) and thereby reflects the envisaged airline response.

## 4. Summary of the results

### 4.1.   The unrestricted scenario

The Schiphol Competition Model as described above is one of the modules in the Integrated Model System available at the Dutch Civil Aviation department. Also a noise contour module is connected to the level of aircraft movements. This enables the policy makers to analyse environmental consequences as far as the number of affected houses in various noise zones is concerned. Another module is the employment and value added module, which derives figures for these variables based on the forecasted traffic and transport volumes at Schiphol Airport. Finally an additional module will be added to translate the physical units of affected houses by noise into monetary values assuming welfare decreases from this noise emissions.[1] Only then a trade-off will be possible between positive effects and negative external effects.

The **effects** now available for the short term forecasts (the year 2002) from the integral model system are summarised in table 4.1:

| TABLE  4.1.Summary of effects of unrestricted development, 2002 | | | | |
|---|---|---|---|---|
| | Traffic Volumes 2002 | | | Noise |
| | Passengers (mln.) | Cargo (mln. tons) | Aircraft Movm's (000's) | Houses in 35 Ke Contours |
| Cautious Scenario | 39.2 | 1.5 | 452 | 14.100 |
| Favourable Scenario | 48.3 | 1.8 | 533 | 23.300 |

The results from table 4.1 emphasise that in an unrestricted growth situation the number of passengers in 2002 will vary between the 40 and 50 million depending on the scenario used. Freight volumes and aircraft movements respectively vary between 1.5 and 1.8 million tons cargo and 450 and 535 thousand movements. Furthermore, the environmental effects reveal that in a favourable unrestricted scenario the maximum of 15000 hindered houses within the 35 Ke zone is exceeded by over 8000, namely 23300 hindered houses. While in the cautious unrestricted scenario the maximum is almost reached already.

One of the reasons why the relative noise impact in the favourable scenario is considerably higher then in the cautious scenario, is the use of extra landing or taking-off runways in peak hours. The approach and taking off routes of these extra runways are situated over densely populated areas. In off-peak periods these runways are avoided as much as possible, of course depending on weather conditions.

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[1]   At this moment the noise nuisance (noise contours) is the only environmental effect in the model. Other environmental effects like emmissions are not yet addressed in the intergral modelsystem, because these effects are not on the critical path of the capacity restrictions which Schiphol Airport is dealing with on the short term (= optimilisation of the existing capacity at Schiphol until 2002).

## 4.2. Restricted Scenario's

In the unrestricted scenario policy measures are inevitable to bring down the noise emission levels. Therefore the next starting point of analysis is some kind of restriction in case of the favourable scenario. A few measures have however already been taken, and we will first evaluate their effects if these would be continued to be implemented until 2003.

In the Physical Planning Document (PKB) for Schiphol the traffic growth has been restricted up to a maximum of 44 million passengers and 3.3 million tonne freight per year. In addition to these restrictions, recently the government has decided that Schiphol is not allowed to accommodate more than 460,000 aircraft movements in the year 2002[2]. Thereafter a new runway is planned to be available which provides new opportunities for further traffic growth.

This implicates that Schiphol now is a slot-coordinated airport. In principle two slot-allocation mechanisms deserve consideration. First of all, the present allocation system based on grandfather rights. This system does not automatically lead to an optimal economic allocation of slots, because a system based on grandfather rights does not take into account any value added. An alternative is a slot-allocation system where slots are free to allocate and (maybe even) tradable. Although this system is not (yet) approved by EU law it would lead to an optimal economic allocation of scarce capacity. The reason for this is that tradable (scarce) slots will push upward the price. Therefore slots will only be allocated to those parties in the market willing and able to pay the higher fares that are inevitably the result from this slot-trading.

The **effects** of these restrictions on the economic and environmental loss and gain based on the favourable scenario are summarised in table 4.2:

| TABLE 4.2. Summary of effects of unrestricted and restricted development, 2002 | | | | | | |
|---|---|---|---|---|---|---|
| | Traffic Volumes 2002 | | | Noise | Economic Costs | |
| | Passengers (mln.) | Cargo (mln. tons) | Aircraft Movm's (000's) | Houses in 35 Ke Contours | Employment (000') | Shadow Costs (bln. Dfl) |
| Cautious Scenario | 39.2 | 1.5 | 452 | 14.100 | | |
| Favourable Scenario | 48.3 | 1.8 | 533 | 23.300 | | |
| | | | | | | |
| 44 mln. pax quotum | 44.0 | 1.8 | 491 | 20 to 22.000 | - 3000 | 2.64 |
| Slot Regulation | 41 to 43 | 1.6 to 1.7 | 460 | 16 to 18.000 | P.M. | >> 1.15 |
| Slot Trading | 45.2 | 0.5 to 1.0 | 460 | 12 to 15.000 | - 8 to - 11.000 | 1.15 |

Table 4.2 demonstrates that in comparison to the favourable unrestricted scenario, a restriction of 460,000 market allocation system results in a reduction of 3.1 million passengers (e.g. respectively 48.3 and 45.2 pax) and a substantial loss of cargo. However, it should be taken in consideration that the uncertainties concerning price-elasticity's of freight are large. Although price-sensitivity relations are well known for passengers, detailed information is almost completely missing for freight. Nevertheless, it is expected that the price-sensitivity of freight is larger than that of passengers. Therefore the model assumes that in case of a market allocation system freight will relatively be hit stronger by the price increase for available scarce slots.

In comparison to the favourable unrestricted scenario the environmental effects of this 'restricted' analysis are positive, since the number of hindered houses within the 35 Ke zone is 8 to 11 thousand less and within the PKB constraints of a maximum of 15000 hindered houses. In this analysis the number of hindered houses varies between 12000 and 15000 houses. The extent to which it will be closer to 12000 or 15000 is dependent on the reaction of the full freighters on the price increase.

The third effect is the economic effect. The direct and indirect employment will decrease, varying from a loss of 8000 to 11000 full time equivalents. This is also caused by the substantial reduction in freight volume, but similarly depends on the behaviour of the full freighters and whether they will avoid Schiphol or not. Furthermore the (shadow-)costs of mobility turns out to be 1,15 billion higher then in a

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[2] The government has granted Schiphol an annual growth in aircraft movements of 20.000, starting on January 1st, 1998. This means that in the period till 2002 the available capacity will reach a maximum of 460.000 (= 360.000 + 5 *20.000)

unrestricted situation. The major part of this increase is on account of passenger transport since freight transport can be and is outplaced at relatively low costs. The increase in costs for the passengers still travelling via Schiphol is 24 guilders per passenger, while the increase for forwarders is 88 guilders per tonne.

So, while the slotrestriction based on market principles is effective in terms of environmental effects (<15000 hindered houses) it is not efficient in terms of economic effects, considering the substantial increase in social costs and the considerable loss in terms of employment and added value.

A more regulated slotrestriction will not hit the freight segment as hard as indicated above, because this category also has the disposal of grandfather rights. In this analysis the passenger segment is affected to a larger extent than the freight segment. As can be seen in table 4.2, five to seven million passengers will no longer travel via Schiphol. The consequence is an immediate increase in mobility (shadow) costs, which will be much higher than the mobility (shadow) costs in the alternative slot allocation mechanism. However it is difficult to judge which segment will be affected the most, because there is no clear insight in the allocation of grandfather rights in the year 2002 and the model is not capable of simulating this. That is why the amount of mobility costs is very uncertain. Nevertheless it can be expected that the mobility costs are larger than 1.15 billion guilders.

In environmental respect this regulated allocation system is more ineffective than the market system, because in the former case full freighters are accommodated. These transporters usually fly older aircraft and operate at night-time, late in the evening or early in the morning. In economic respect the results are even worse compared with the market allocation mechanism, because less passengers are accommodated on Schiphol and the costs associated with avoiding Schiphol is much higher for the passenger segment than for the freight segment. As to the employment effects the difference between the two allocation systems is less clear and is probably mainly depending on the reaction of the freight segment when everything is left to the market.

Table 4.2 also clarifies that a restriction of 44 million passengers (PKB Schiphol) is not only more inefficient than each of the two slotallocation systems, but is also worse for the environment (when noise is considered). The social costs are increasing by 2.6 billion guilders and the number of hindered houses is well above the maximum of 15000, namely 20 to 22 thousand hindered houses. This is caused by the fact that the number of aircraft movements is more than 490.000 and full freighters are accommodated on Schiphol.

It must be pointed out that both the increase in costs as a consequence of growth restrictions on the aviation industry in the Netherlands and the related loss in employment and added value are consistently underestimated. This is based on the following two aspects:

- Because of a more stringent policy the growth potential in recent years has not been fully exploited intentionally.
- Although the extra growth-potential spinning of the alliance between KLM and Alitalia has been taken into account in the model not all extra growth-potential of (future) alliances are included (e.g. the effects of the alliance between Continental and Northwest or maybe an alliance with an East-European carrier).

### 4.3.   Other measures

The above measures have the intention to reduce traffic volume to certain levels, either by regulatory or market mechanism. Nevertheless the relation with the noise level is an indirect one. In taking these measures it is aimed that also noise levels are reduced in line with this, although the extent to which noise is reduced varies considerably.

Other measures, more directly related to noise emissions, may therefore be considered. In this analysis the efficiency and effectiveness of three types of measures are worked out.

- **price control measures**; The aim of these type of measures is to give an incentive to airlines to use the environmental capacity more efficiently via the price mechanism. That is, to encourage aircarriers to use the most quiet aircraft, preferably not in the night or early morning and late evening period.

- **measures concerning flight scheduling**; The aim of these kind of measures is to spread the flight pattern of carriers in such a way that the use of extra runways in peak times is less necessary.

- **technical operational measures**; The aim of these kind of measures is to optimise the use of airspace- and runwaycapacity. In this way the number of aircraftmovements within the 15.000 houses contour can be maximised without negative consequences for safety.

A surcharge may be considered according to the use of environmental capacity. The use of environmental capacity is depending on the noise emissions of the aircraft and the time of the day when the aircraft is taking off or landing. In noise computations time penalty factors are used for different hours of the day. Both measures have been evaluated in their effects. A surcharge has been set on aircraft movements according the use of environmental capacity. The surcharge has been set in such a way , that - on average - the resulting fare increase for passengers will be Dfl. 50 per return ticket. However passengers flying in the most noisy aircraft are supposed to pay Dfl. 100, whereas passengers in the most noise friendly fleet are not supposed to pay any surcharge. Furthermore night flights do use considerable more environmental capacity, and therefore the surcharge on passenger movements is assumed to be Dfl. 250, when taking off or landing is in the night period. The charge is lower according to the time of day of taking off or landing.

Furthermore some analysis have been done assuming peak spreading of the latest evening arrivals. These arrivals are not followed by departures on the same day, and consequently there is no connectivity loss to be expected if this peak is spreaded in such a way that the use of a second landing runway is not necessary. As mentioned before the use of this second runway does affect many residential areas, at the evening period when a noise penalty factor is also applied.

Finally some analysis has been done assuming improvements in technical operational procedures. These improvements refer to landing and take-off procedures and to runway use conditions with respect to weather conditions. It is expected that these procedures may also help in reducing perceived noise levels.

In table 4.3 the effects of the above mentioned types of measures are summarised.

| TABLE 4.3. Summary of effects of unrestricted and restricted development, 2002 | | | | | | |
|---|---|---|---|---|---|---|
| | Traffic Volumes 2002 | | | Noise | Economic Costs | |
| | Passengers (mln.) | Cargo (mln. tons) | Aircraft Movm's (000's) | Houses in 35 Ke Contours | Employment (000') | Shadow Costs (bln. Dfl) |
| Cautious Scenario | 39.2 | 1.5 | 452 | 14.100 | | |
| Favourable Scenario | 48.3 | 1.8 | 533 | 23.300 | | |
| | | | | | | |
| 44 mln. pax quotum | 44.0 | 1.8 | 491 | 20 to 22.000 | - 3000 | 2.64 |
| Slot Regulation | 41 to 43 | 1.6 to 1.7 | 460 | 16 to 18.000 | P.M. | >> 1.15 |
| Slot Trading | 45.2 | 0.5 to 1.0 | 460 | 12 to 15.000 | - 8 to - 11.000 | 1.15 |
| | | | | | | |
| Levies by noise cat. | 46.5 | 1.6 | 509 | 15 to 17.000 | - 3.000 | 1.20 |
| ,. by time of day | 46.4 | 0.8 to 1.2 | 498 | 14 to 17.000 | - 4 to - 7.000 | 1.20 |
| | | | | | | |
| Evening peak spr. | 48.3 | 1.8 | 533 | 18 to 20.000 | P.M. | |
| Tech. Operat. Meas | 48.3 | 1.8 | 533 | 14 to 17.000 | | |

Table 4.3 puts forward that each of these measures results already in a considerable reduction of the number of hindered houses in relation to the unrestricted favourable scenario:

- A surcharge on noise levels per aircraft results in 6 to 8 thousand less hindered houses or a reduction of approximately 30%. This charge particularly encourages airlines either to shift within

their fleet to operate more noise friendly aircraft on Schiphol or to invest in a more modern fleet, of course depending on the surcharge set. Similar argumentation holds when surcharge is set on operations for different times of the day. Both types of measures have been set in such a way that the total shadow costs are similar. Both measures do not differ in effects for passenger, but when charges are set for night flights, we see cargo being hit more severely, as the cargo segment is using Schiphol relatively more in the night period than the passenger segment. Consequently also total employment effects are more negative in case of levies by time of day. Although also with these type of measures the shadow costs are high, we must conclude that the efficiency of these measures with respect to noise reduction is higher when compared to the regulatory restrictions.

- An adjustment of flight schedules, where the last evening arrival wave is levelled off results in a reduction of hindered houses of 3 to 5 thousand or 15% less. As the costs and traffic loss is expected to be low, if not zero, we must conclude that the efficiency of these measure is high. Finally also the effects of technical operational measures are considerable in the effects on noise reduction, although their implementation costs and efforts are high. It is generally felt that the effects of this type of measures are more promising on the longer term compared to the short term period observed in this analysis.

The preceding findings show that separate implementation of the latter type of measures already leads to considerable reductions in noise levels. This may give an idea about the potential reductions when these measures are implemented as some kind of mix between them. With a combination of measures it is expected to be possible to achieve still a considerable growth to levels of more than 500.000 aircraft movement and still to respect the environmental limits that have been set.

## Conclusions

For the time being the following conclusions can be drawn:

- Capacity restrictions on Schiphol do not offer the final solution for the noise problems at Schiphol. These restrictions are in economical respect inefficient, because of the high social costs, and the reductions in noise emissions are insufficient

- The three other optimisation measures are however more promising. There are certainly economic cost involved, but on the other hand the efficiency with respect to noise reduction is considerable higher. With some kind of combinations of the measures mentioned, it is expected that growth level - respecting the environmental limits - may be reached beyond the slot control limits that have currently been set.

"Airport Performance in Stakeholder Involvement and Communication Strategies: A Comparison of Major Australian and North American Air Carrier and General Aviation Airports"

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by

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# "Airport Performance in Stakeholder Involvement and Communication Strategies: A Comparison of Major Australian and Northern American Air Carrier and General Aviation Airports"

## By John Black*

## Abstract

Communication strategies to engage key stakeholders and communities is a neglected aspect on airport management performance. Benchmarking studies have been conducted at selected airports in Australia and the U.S.A. where facilities are being expanded to accommodate traffic growth. Major issues are aircraft noise, air quality and ground access.

The paper reports on environmental management studies, in general, and corporate communications strategies, in particular. Examples of best practice are drawn from U.S. airports. Although environmental management and community participation are established for the Federal Airports Corporation, the recent privatisation of its 22 airports (except for those in the Sydney basin) means that new challenges are faced by airport managers. Interviews conducted as part of the benchmarking study and research into public relations leads to recommendations for corporate change that include more symmetrical communications strategies.

Governments ... "must give people a say in making a
decision. And really that is the principle of modern
environmental impact assessment."
(Barry Carbon, Executive Director of the Environmental
Protection Agency, in *ERM Mitchell McCotter Newsletter*,
No.7, December, 1995, p2)

## 1. Introduction

Better procedures for effective stakeholder (interest group) and community involvement
is one of the challenges of improved organisational performance of Australian airports.
This is supported by a Commonwealth of Australia review of public participation in
environmental impact assessment and experience at Sydney (Kingsford Smith) Airport.
Legal and invited opportunities arose for public involvement in the environmental
impact assessment of the third runway at Sydney (Kingsford Smith) Airport and a
Commonwealth government requirement that the community be involved in the
preparation of the environmental mitigation programs (noise management and air quality
management plans) at the airport with its third runway (Mitchell McCotter, 1994 a, b, c,
d). However, there was widespread disagreement and dissatisfaction expressed by all
parties on both process and outcome. Much of this surfaced at the Select Committee on
Aircraft Noise in Sydney (Commonwealth of Australia, 1995) - an inquiry set up by the
Australian Democrats a few months after the opening of the third runway in November
1994 in response to community concerns over aircraft noise. Problems associated with
current procedures of public participation have also been highlighted by controversies
on finding an acceptable site for a second airport in the Sydney basin.

The notion that the community be involved in the preparation of airport environmental
management plans is a recent one in Australia. The decision by the Commonwealth
Government in 1991 to construct and operate a third runway at Sydney (Kingsford
Smith) Airport was on the condition that, *inter alia* the community be involved in the
preparation of noise management and air quality plans. The requirement that the
community be involved arose from the determination on the Proposed Third Runway
Environmental Impact Statement (Kihhill Engineers, 1990, 1991). A Community
Advisory Committee (CAC) was established in 1992. Documented case studies
attempting to critically assess the effectiveness of community involvement in airport
planning are rare. As this was the first time in Australia that the community have been
involved in environmental management plans an assessment of the **process** of
participation represents an important contribution for other studies that may follow.

More generally, this paper provides a perspective on the performance of airport
management in terms of their communication strategies and ways of involving the
community when there are airport expansion programs underway. Research into
communications strategy and stakeholder involvement has been undertaken at
Australian and at US airports. After outlining the research design (Section 2),
environmental management and communication strategies at US airports are described.
(Section 3 and 4). The background problems that lead to this study of Australian and
other major international airports are explained and the current policy context for public
participation in Australia is outlined in Section 5. The main contribution of this paper
is to present a theoretical framework for interpreting the results of airport case study
approaches to communication and public involvement, and to outline principles of
organisational change (Section 7)

## 2. Research Design

The research design for this study of community involvement derives from
organisational benchmarking. Airport operators are totally familiar with
"benchmarking": the European "Big Four" (London Heathrow, Paris Charles de
Gaulle, Frankfurt am Main and Amsterdam Schipol) regular meet to discuss

performance issues. Information is a resource which can improve the decision-making process within an organisation and comparative studies of practice can be instructive. As used here benchmarking is a continuous, analytical process for understanding and assessing the strengths and weaknesses of community involvement practices and communication strategies at airports that represent best practice. The technique has been applied to compare the performance in environmental standards and management at European airports by airport managers but no similar study has been undertaken of communication strategies and stokehold involvement.

The purpose of the overall research design study is to investigate corporate commitment, practice, procedures and experience at selected Australian and overseas airports in the area broadly defined as stakeholder involvement. Because of the overlap between consultative processes (however defined) and communication processes (public relations, corporate relations, community relations) the study emphasises associated communications strategies and programs. Airport owners consult with a range of key stakeholder (interest group) in undertaking their business but the specific examples of consultation and communication relate to major environmental issues. Thus, the main focus of this study is the communications that arise with the impact of aircraft operations on the noise, air quality and land-side access when there are major airport developments (new runways, terminal buildings, new transport links and parking facilities).

Benchmarking is defined[1] as a continuous, analytical process for understanding and assessing the practices of airport[2] operators that are identified as representing world-class, state-of-the-art best practice in community involvement. The purpose of this study is to allow organisational comparison and functional learning, to help develop consultation process objectives and to suggest goals and measures of effectiveness (performance indicators). Benchmarking is a useful management tool (Bogan, and English, 1994; Boxwell, 1994; and Crocker, etal, 1996).

Spendolini (1992, pp 46-50) has constructed a five-part generic benchmarking model which has been adapted for this study, as follows:
(1) Define the topic of (stakeholder involvement, community participation and communication strategies was suggested by the Federal Airports Corporation as a critical area for the organisation);
(2) Resources did not permit the luxury of a benchmark team and so this study is based on consultations at airports by the researcher;
(3) The identification of information sources that will be used (employees, consultants, stakeholders, government sources, industry reports), is an important part of the methodology of benchmarking;
(4) Specific data collection methods are selected and information is collected to an established protocol, then summarised for analysis together with recommendations;
(5) The final part specifies any next steps and action that might arise.
In consultation with senior management at Sydney (Kingsford Smith) Airport a briefing package was prepared and sent to airport managers.

In this package the "prompts" for structuring the interviews during each site visit provided a comprehensive picture of the scope of information requested and questions to be posed. The material sought can be classified into four areas:
(a) corporate communication strategies (public relations, marketing), including listing of key stakeholders ("publics", "target audiences" or "interest groups"), main methods of techniques of consultation/involvement, processes of obtaining

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[1]  Continuous because static snapshot does not cover dynamic context; analytical - recommended set of actions in some particular order (not a loosely structured information-gathering exercise); once benchmarking is completed there is a call for action based on references to comparison and change.
[2]  Non competitor industries are also analysed to gain insight into consultation and community involvement procedures.

feedback (opinion polls, user surveys, consultative committees) and uses of such information within the organisation (corporate affairs);
(b) documents on airport development planning;
(c) more specific documentation of studies dealing with noise abatement, insulation, acquisition and compensation schemes, air quality (emission inventory, monitoring) and land-side transport access (employee and public parking, road/rail infrastructure investment); and
(d) stakeholder (interest group)/community involvement in environmental planning or monitoring studies - organisational structures, different methods used, effectiveness, examples of good practice, what worked, what did not, and why.

## 3. Environmental Management at US Airports

There are three big environmental issues at international airports when substantial landside and airside facility expansion occurs. The most vexing of these relates to aircraft noise associated with increased movements of passenger and freight aircraft. A quarter of a century ago King (1973) had compiled at extensive bibliography on the effects of airport noise on people and property with chapters dealing with human health (item numbers 692 to 1351) and property values (item numbers 1352 to 1519). The second issue is aircraft emissions, emissions from airport vehicles and emissions from transport to and from airports. Metropolitan air quality is of widespread concern across the transport sector, and of particular relevance in California (Air Quality Certificate programs have been established by the State Air Resources Board). The third issue is groundside airport access. Inter-modalism is an element of the Inter-modal Surface Transportation and Efficiency Act (ISTEA), and the recognition of multi-modal planning for ground access is being promoted with a manual as guidelines for practice Bellomo-McGee Inc (1996).

Community involvement in U.S. airport planning, when compared to Australian practice, has a long history. The U.S. Federal Aviation Administration (FAA) recognised in the 1970s that in order to create a climate to allow the expansion of aviation and airport services to meet projected traffic demands airport managers had to be seen as concerned neighbours by those who live and work nearby to airports. They felt that community involvement might provide the best mechanism in developing acceptable approaches to noise, pollution and groundside traffic congestion while enhancing the perception of aviation as a concerned neighbour (U.S. Department of Transportation, 1979, p.i).

The Federal Aviation Administration actively encouraged community involvement in all FAA-sponsored programs. The legal mandate for community involvement is provided in Public Law 94-54 which states (Section 16(c)(3)):

> "No airport development projects may be approved by the Secretary unless he [sic] is satisfied that fair consideration has been given to the interest of the communities in or near which the projected is located."

A community involvement manual (U.S. Department of Transportation, 1979), based on then current best practice in the fields of aviation, highway planning, water resource planning and forest and recreation land management, was designed to provide information on how to design and conduct effective community involvement programs. It recognised that in effective community involvement campaigns various methods for communication and problem solving (public meetings, advisory groups, workshops and public hearings, for example) are combined into a total program designed to ensure that concerns and needs of all the participants are considered in the decision making process.

For example, airports in the U.S.A. are further advanced than in Australia in

formulating noise management plans and in engaging the communities of interest. Objectives of the Federal Aviation Regulation (FAR) Part 150 promulgated in 1984 are : to establish a national uniform system of describing aircraft noise exposure; to provide technical assistance in the development and to describe land-use compatibility criteria. The focus of a FAR Part 150 program is to produce a comprehensive set of noise abatement actions and mitigation measures for various individuals, agencies and organisations each of whom has specified implementation responsibilities. Specific documents must be submitted to the Federal Aviation, including noise exposure maps (with contours drawn representing $L_{dn}$ 65, 70 and 75 based on current and five-yearly forecasts of operations) and the prescribed solution to noise abatement. FAR Part 150 contains a separate checklist for the noise exposure map and for the noise compatibility program, and appropriate consultation is one aspect of the review conducted by the FAA. Table 1 reproduces that part of the checklist dealing with consultation. The left-hand-side of the table pose the questions that should be addressed by the operator in reviewing the adequacy of the noise exposure map and noise compatibility program. The three blank columns to the right-hand-side of the table would be completed by the operator according to the legend at the bottom of the table.

**Table 1: Consultation Checklist for Noise Exposure Map and Noise Compatibility Under Federal Aviation Regulation Part 150 Program**

| Item | Operator's Review | | |
| --- | --- | --- | --- |
| | A | B | C |
| **Noise Exposure Map (NEM)** | | | |
| 1. Is there a narrative description of the consultation accomplished, including opportunities for public review and comment? | | | |
| 2. Are the consulted parties identified? | | | |
| 3. Do they include all those required by regulation (150.21(b); AISO, 105a)? | | | |
| 4. Does the documentation include the operator's certification, and evidence to support, that interested persons have been afforded adequate opportunity to submit their views, data, and comments and, if there were comments, that they are on file with the FAA region? | | | |
| **Noise Compatibility Program (NCP)** | | | |
| 1. Documentation includes narrative of public participation and consultation process? | | | |
| 2. Identification of consulted parties: (a) all parties in 150.23(c) consulted? (b) public and planning agencies identified? (c) agencies in (b) correspond to NEM? | | | |
| 3. Satisfies 150.23(d) requirements: (a) documentation shows active and direct participation of parties in 2 above? (b) participation was prior to and during work development of NCP and prior to submittal to FAA? (c) indicates adequate opportunity afforded to submit views, data, etc? | | | |

**4.** Evidence included of notice and opportunity for a public hearing on NCP?

**5.** Documentation of comments:
(a) includes summary of public hearing comments, if hearing was held?
(b) includes copy of all written material submitted to operator?
(c) includes operator's responses/disposition of written and verbal comments?

A - Yes/No/Not applicable
B - Chapter or page reference in technical report of NCP
C - Notes of comments (for example, under 5(b) material may be provided under separate cover to the FAA Regional Director)

(Source: based on Federal Aviation Regulation Part 150)

For example, the Noise Compatibility Program at Washington National Airport from 1987 to 1990 involved the active participation of planning agencies, air carriers, the Federal Aviation Authority, the Metropolitan Airports Authority and other interested parties. Citizens were represented on two committees which commented on the development of noise exposure maps and on the subsequent development of the Program. The Committee on Noise Abatement at National and Dulles Airports (CONANDA) - created in 1985 by the Metropolitan Washington Council of Governments' Board of Directors - served as a special-purpose body to monitor noise problems and to make recommendations to the Board of Directors and to the airport authority. This committee, which met, on 11 occasions between September 1987 and May 1989, was composed of elected members from local government, with non-voting citizens and aviation industry representatives. Analysis of committee membership as of September 1989 reveals the composition and voting powers shown in Table 2.

Table 2 : Composition of Committee on Noise Abatement at National and Dulles Airport, 1989.

| Group | Number | Voting |
|---|---|---|
| Elected local government members | 6 | Yes |
| Elected government officials | 2 | Yes |
| Citizen representatives | 3 | No |
| Aviation industry representatives | 3 | No |
| Metropolitan Washington Airports Authority | 1 | No |
| Observers* | 40 | No |

* includes 9 citizens

(Source : based on Howard Needles Tammen & Bergendoff, 1990, Appendix C)

## 4. US Airport Communication Strategies

Fieldwork at west coast U.S. airports in California, Oregon and Washington states was completed from October to December, 1996. Airports on the east coast - in the New York and in the Washington D. C. regions - were surveyed in January 1997. Fieldwork for the benchmarking study of California airports was undertaken at the nine busiest airports where the impact of aircraft operations on the surrounding community is expected to be the greatest (Table 3). About 7.5 per cent of all national air travellers

emplaned or deplaned at Los Angeles and San Francisco airports. As with passengers, the Los Angeles and San Francisco region airports dominate the transport of cargo. Aviation is the most important transport mode in the export abroad of goods: in 1987, 60 per cent of exports (as measured by dollar value) left the state by plane (The California Commission on Aviation and Airports, 1989, p. 2).

**Table 3: Passenger Traffic (Millions) at Major Californian Commercial Service Airports\*-Enplanements and Deplanements, 1975 to 1993**

| Airport | 1975 | 1980 | Year 1985 | 1990 | 1993 |
|---|---|---|---|---|---|
| Los Angeles | 23.72 | 33.04 | 37.65 | 45.81 | 47.84 |
| San Francisco | 16.36 | 22.06 | 25.00 | 30.39 | 32.06 |
| San Diego | 4.49 | 5.10 | 7.94 | 11.21 | 11.94 |
| Oakland | 2.21 | 2.41 | 4.13 | 5.51 | 7.50 |
| San Jose | 2.31 | 2.89 | 4.71 | 7.13 | 7.04 |
| Ontario | 1.29 | 2.00 | 3.65 | 5.42 | 6.19 |
| Orange County | 1.58 | 2.38 | 3.29 | 4.59 | 6.11 |
| Sacramento | 1.93 | 2.27 | 2.89 | 3.63 | 5.32 |
| Burbank | 1.63 | 1.92 | 2.92 | 3.50 | 4.35 |
| State Totals | 58.71 | 77.39 | 96.54 | 123.12 | 132.80 |

\* The State's definition of a commercial service airport is one that received scheduled service as of 15 January 1987. The Federal definition also requires an airport to enplane more than 2,500 passengers annually.

(Source: based on California Department of Transportation, Aeronautics Program, 1994, Table 15, p 147).

Interviews of airport managers were undertaken at Portland, Seattle-Tacoma, New York JFK, New York Law Guardia, Newark, Westchester County, Baltimore-Washington International, Washington National and Washington Dulles. No attempt is made in this paper to analyse systematically the contents of each airport management communication strategy and the methods used in community involvement. In the following part of this section some illustrative examples are given before returning to the status of public participation at Australian airports.

The San Francisco International Airport Commission consists of five members appointed by the Mayor of San Francisco for four-year overlapping terms, with all appointments subject to rejection by a two-thirds vote of the Board of Supervisors. Senior airport management is lead by a Director, who as the chief executive officer, has full authority to administer the affairs of the Commission. Under the Charter, the Director is appointed by the Mayor from candidates submitted by the Airport Commission. Airport performance measures are divided into three major source areas: safety and security; customer service; and business operations. Publication of such information as airport performance is seen "to strengthen our accountability to the airport passengers, employees, and citizens of San Francisco" (City and County of San Francisco, San Francisco International Airport, 1996, p.1). One important component of customer service is to ensure compliance with Federal and State noise regulations in order to protect the surrounding environment from excessive aircraft noise impacts.

The airport's noise mitigation program includes US$120 million for home insulation and the phasing out of Stage 2 aircraft by the year 2000. Of particular significance was the establishment by the Director of the Airport, Mr. Louis Turpen, of the Airport/Community Roundtable in 1981 following the time consuming and tedious settlement of numerous small claims from property owners associated with noise. As a public forum, the Roundtable brings together representatives of San Francisco Airport, state and federal transport agencies, control tower personnel, airline representatives and the general public to talk about issues and to generate innovative methods. Community members have also participated in the development of the US$2.4 billion Master Plan program, a "people mover" system for the terminals and ground access improvements. The value of countering community misperceptions through information and education

is reflected in the technical quality of the publication of the San Francisco International Airport/Community Roundtable *Monitor.*

The City of Los Angeles Department of Airports, which employs 1695 staff (January 1995) operates and maintains four airports - Los Angeles International, Palmdale Regional Airport, Ontario International and Van Nuys Airport (general aviation). The Department is a financially self-supporting branch of the City of Los Angeles. Los Angeles International Airport has historically subsidised, and is expected to continue to subsidise the operational and maintenance expenses for Palmdale and Van Nuys (City of Los Angeles, Department of Airports, 1995, p 28). Los Angeles International Airport is governed by a five-member Board of Airport Commissioners. Board members are appointed by the Mayor and approved by the City Council. Responsibility for the implementation of the policies formulated by the Board and for the day-to-day operations of the airport system rests with the senior management of the Department of Airports. The Executive Director is appointed by the Board. There are five Airport Divisions - Operations and Administration, Planning and Engineering, External Affairs, Business Development and Surface Inspection. The formal business of managing the airport is conducted through the five-member Board of Airport Commissioners (BOAC) who meet every two weeks. Board meetings are accessible to all individuals (signing assistance for the hearing impaired can be arranged when requested 3 days in advance). Typically, the agenda papers contain: (a) roll call; (b) discussion and consideration of the formal agenda ; (c) management reports and information; (d) matters that have arisen since posting the agenda; (e) Commission requests for calendaring of future agenda items; and (f) comments from the public. Under Californian law (Brown Act) items must be placed on the agenda for consideration and resolution. Members of the public give notice of wishing to address the meeting.

The greatest contemporary challenge facing the Los Angeles Department of Aviation is building community awareness of the LAX Master Plan to modernise the airport to handle 4.2 million tons of freight and 98 million passengers in 2015. Four scenarios - with either five or six runways or with connections to nearby Hawthorne Airport for a commuter runway, and all with new terminal buildings and cargo facilities - were released to the public on 13 December 1996. There is one standing committee that involves community representation established some 25 years ago - the LAX Area Advisory Committee. It has three representatives of each of the six communities surrounding the airport. The Department of Airports provides the meeting room (Los Angeles International Airport Board Room) administrative support and technical information (for example, volume of air traffic, summary of monthly noise complaints) requested. With such a long pedigree extending back over a time when the airport has generated many issues for the surrounding community it is inevitable that there is differing views on the role of this advisory committee. Part of the airport's commitment to being a good neighbour has included holding more than 200 meetings with business and community leaders. A public relations firm has been engaged to achieve "consensus planning", to organise community workshops, and to meet with residents groups and chambers of commerce.

Ontario International Airport (on a site of 1450 acres) is located 56km east of downtown Los Angeles in the west of San Bernardino County. Within an hour's drive four counties are reached with a catchment population of 6 million people. The airport handles currently about 6 million passengers and 250,000 tons of cargo each year. In May 1996, Hensel Phelps Construction Company (Colorado) was awarded a US$107.2 million contract to build two domestic passenger terminals totalling 530,000 sq. ft. to accommodate up to 10 million passengers. These are part of a US$250 million expansion project for an apron with space for aircraft parking, 26 gates, roads and parking, landscaping, utilities to be completed in 1999. A third terminal is planned to be built when passenger counts for two consecutive years top the 10 million mark.

The Public Affairs Department provides public information on this project with a well conceived three-year strategic plan (1997-2000), following years of frustration to

airport management on terminal expansion when construction was delayed because of concerns by locals of the possible presence of the kangaroo rat. The next three years effort of the Ontario International Airport Public Affairs Bureau will be focussed on four areas - cargo, new passenger terminals, passenger convenience and employees (6,600 at ONT). The Bureau is proactive with a three-year plan, priorities for each year and specific programs in each area. For instance, efforts to raise awareness of Ontario International Airport as a cargo and logistic centre include co-producing the regions first annual International Cargo Conference and Expo, developing a network of Southern California "Inland Empire" cargo professionals, publishing a monthly cargo newsletter and increasing advertising presence in regional and national trade journals.

Amidst controversy about airport expansion The Friends of Ontario International Airport Association have been strong advocates of a growing airport. The Association, founded in 1963, is the first and oldest organisation of its type in the world. Its purpose is to promote the use and development of the airport. With this common bond The Friends is a non-partisan, nonsectarian organisation that includes representatives from 39 different communities in four airport - adjacent counties that cover a wide spectrum of social and political diversity.. During the past 15 years the Association has informed citizens of the aviation services at Ontario International Airport, sought additional air carrier services, encouraged citizen support of the airport and worked with the aviation industry to improve the convenience of the airport. Sponsored projects include: (a) the publication and distribution of flight schedules; (b) position papers on airport development; (c) airport information brochures (for example, the monthly *Friends Flyer*); (d) monthly guest speakers; and (e) testimony at public hearings.

At Burbank Airport the corporate communications group has increased from 3 to 6 given the strong imperatives for communication with a range of publics. Since 1989/90 the airport has pursued an aggressive marketing campaign. A newsletter, primarily directed at airport users and businesses, has a circulation of 40,000 and invites call back for further information. Advertising in the print and radio media is directed at the local travelling consumer. Passenger surveys attempt to measure cost effectiveness through customer awareness of advertisements. There are 9 commissioners for the airport representing three neighbouring city councils. Board meetings held bi-monthly are broadcast over cable television (with a repeat broadcast) with programs covering airport issues and panel discussions. The corporate philosophy to communications is grounded in private-sector approaches with an absence of bureaucratic structures. During the development of the Part 150 Noise Study there developed the practice, which continues, of small group meetings with interested parties or one-on-one meetings. The result has meant there are no substantial coalitions opposing airport management.

Since it opened in 1967 Sacramento Metropolitan International Airport has grown at a rate that has exceeded expectations. Annual revenues have outstripped costs in every year to date except one. The airport is owned by the County of Sacramento; its Department of Airports operates the airport. The Department was created the Sacramento County Code in 1963 as a department within the County of Sacramento with the purpose of efficient planning, development and operation of public air transport services. The Department of Airports is also "responsible for assuring residents of Sacramento and the immediate surrounding areas of minimal environmental impact from air navigation and transportation" (County of Sacramento Department of Airports, 1995, p. 5).

Given the local ownership of the airport, the Department strives to keep the Board informed - both formally and informally. There is a Board meeting and agenda every Tuesday which acts as a conduit for communication covering information and developments at the airport and to hear of potential issues and concerns. Complaints from the public may be directed to an elected representative on the Board before they are received by the Department. As the Board signs every lease and contract , and signs for the acceptance of FAA grants and associated conditions it is efficient management to

ensure a candid and open process of two-way communication. In addition, the Director of Airports attends Town Council meetings that are open to the public when there are airport matters on the agenda.

As Town Council meetings, or other public forums, may be attended by a vocal minority other forms of feedback are required. One obvious way is the booth at the annual *Sacramento Bee* fair which by listening to staff and taking notes of unsolicited public opinion both positive and negative. Sacramento Metropolitan International Airport is proactive with promoting a public image with annual advertising campaigns. By setting annual marketing objectives for each campaign effectiveness tends to be measured by passenger market share analysis or whether user behaviour has changed. Specific examples include: "Goodbye & Fare Well" - black and white newspaper advertisement , winner of the 1992 IABC Crystal Award; "Presenting Five Reasons Why You Should Fly Out of SMA" (quick getaways, happy returns, competitive prices, no hidden costs and lots of flights); persuading travellers to use airport shuttles (The Sacramento Advertising Club gave the 1992 Gold Award to Renyon Saltzman Wagraff & Siegel for "Original Music-Airport Shuttle") and the campaign that made its debut on television in November 1996 - "Fairy Tale" by Runyon Saltzman & Einhorn, promoting the airport and its new Terminal A under construction and to be opened in 1998. The TV segments ran through to June 1997 on shows such as Seinfeld, Law & Order, ER and 48 Hours, and also on local news programs. Print ads are also part of the advertising campaign.

The Sacramento region exceeds California state air quality standards. A state Air Quality Certificate was required in 1982 to receive federal funds for a second runway. This Certificate limited airfield operations to 139,000 annual flights, 7 million annual passengers and permanent parking spaces of 5,470 vehicles. With the average number of vehicle trips to and from the airport at 30,000 per day (4,5000 parking per day) in 1995 the thrust of the communication strategy has been promoting voluntary employee and patron trip reduction program, deg shuttle buses using alternative fuels (CNG, methanol and electric) and consolidating bus services into a central location.

## 5. Community Involvement - Australian Airports

In Australia, there is little published on community participation in theory and practice in relation to airport developments. This is in contrast to numerous case studies in urban development reported in selected references on community consultation and participation from 1980 to 1994 (Sarkissian, 1994a, pp. 213-221; Sarkissian, 1994b, pp. 85-92; and Perlgut, 1994, pp. 93-102). Sarkissian (1994c, p. 13) contrasts models of public participation at the local level in Australia and the United States. Citizens advocates in the USA insist that true participation would be synonymous with democratisation of resource allocation decisions, decentralisation of government design making, deprofessionalisation of bureaucratic judgements and demystification of information and decisions. In Australia, the current participating models are typically described as paternalism, conflict and co-production (direct involvement of non-elected interest groups in the operation of government).

At the start of the research in 1996 the Federal Airports Corporation operated on behalf of the Commonwealth of Australia 22 air carrier and general airports aviation. As of mid-1998, all airports, except those international general aviation airports in the Sydney basin, have been privatised. As noted by Latham (1998) part of the explanation rests with reducing the Federal Government's budget deficit. These airports handled around 54 million passengers in 1993/94 which made the Corporation one of the world's largest airport owners and operators (Federal Airports Corporation, 1995, p. 1). Given this size and geographical diversity of operations it is obvious that consultation with government, commerce, industry, consumer groups and other bodies and organisations will take on many different forms specific to the nature of the issue and location of the airport. "One of the fundamental rules of benchmarking is to know your own

processes, products and services before you attempt to understand the processes, products and services of another organization" (Spendolini, 1992, p. 151).

Australian Commonwealth Government policy and guidelines on public participation and communication and the legislative requirements of the Federal Airports Corporation Act broadly define the Corporation's responsibilities on stakeholder involvement. The Intergovernment Agreement on the Environment (IGAE) aims to provide the basis for a new co-operative approach to governmental management of environmental issues in Australia. Schedule 3 endorses the commitment to public involvement:

"• there will be full public disclosure of all information related to a proposal and its environmental impacts, except where there are legitimate reasons of confidentiality...;

• opportunity will be provided for appropriate and adequate public consultation on environmental aspects of proposals before the assessment process is complete;

• mechanisms will be developed to seek to resolve conflicts and disputes over issues which arise for consideration during the course of assessment process."

Two international agreements are also relevant in Australia to the above public participation in the environmental impact assessment process: Agenda 21; and the Rio Declaration.

A comprehensive, public review of the Commonwealth of Australia environmental impact assessment legislation and process was announced in October 1993, followed by a discussion paper distributed to the public in November 1994 (Commonwealth of Australia, 1994) inviting submissions, to be treated as public documents, by the end of March 1995. This review had "a strong commitment to ongoing consultation with all environmental impact assessment stakeholders" (Commonwealth of Australia, 1994, p 1). Following this consultation the Commonwealth Environment Protection Agency (EPA) adopted guiding principles (Commonwealth of Australia, 1994, p iii) to govern the development of a reformed environmental impact assessment process and to act as benchmarks to enable stakeholders to monitor performance of the process, including: real opportunities for public participation in government decision making; open and transparent processes, and; certainty of application and process to all participants, including the community, governments, industry and the project proponents. Effective public participation is seen as an essential element of an improved environmental impact assessment process with three key strategies to improve public review of environmental documents: access to information, including a public registry mechanism (similar to the proposed Canadian EIA legislation); community resourcing; and the participation of non-English speaking background and indigenous communities (Commonwealth of Australia, 1994, pp. 40-43).

There was a legislative requirement for the Federal Airports Corporation to engage in consultation activities which is carried forward to the owners of all Australian airports. The *Federal Airports Corporation Act 1986* (Section 6) prescribes the functions of the Corporation: to operate Federal Airports, and participate in the operation of a joint-user aerodrome, in Australia; to establish airports and Federal airport development sites; and "to provide the Commonwealth, governments, local government bodies, and other persons who operate, or propose to operate, airports or facilities relating to airports (including airports and facilities outside of Australia) with consultancy services relating to the development and operation of these airports or facilities" (Commonwealth of Australia, 1994, p. 5). In performing its functions the corporation shall , *inter alia*, endeavour: to ensure that, as far as practicable, the level of noise at airports is not such as to be detrimental to the communities near airports (s 6 7 (2c)); to ensure that, as far as is practicable, the environment is protected from the effects of, and the effects associated with, the operation and use of aircraft ...operating to or from Federal airports (s 6, 7(2ca)); to ensure that the corporation and the communities served by Federal airports are good neighbours (s 6, 7 (2f)). Consultation is part of the Act (Section 12):

"In the performance of its functions and the exercise of its power under this Act, the Corporation shall, where appropriate consult with government, commercial, industrial, consumer and other relevant bodies and organisations"
(Commonwealth of Australia, 1994, p. 11).

In 1996 the Environmental Management Plan was revised as an "Environmental Management Manual" in a format consistent with the draft International Standard ISO 14000. The FAC Corporate Environmental Policy Statement contains several points of direct relevance to the topic of stakeholder involvement:

"....set in consultation with relevant authorities and the community, specific environmental objectives and targets to reduce our environmental impact and prevent pollution ...continually measure, monitor, report and improve upon the environmental performance defined by our objectives and targets, and promote the Corporations (sic) commitment to the environment, to our employees, tenants, customers and neighbours." (Federal Airports Corporation, 1996 p. 2).

One specific environmental objective is to "ensure that procedures exist to facilitate effective internal and external communication of environmental information" (Federal Airports Corporation, 1996, p 10). The Environmental Management Manual summarises the people responsible for a total of 21 environmental management procedures (EMP), the actions required and completion dates. Of importance to this study is EMP No 4 which deals with community consultation. The performance target is to "implement procedures to keep the community informed on environment management at Sydney Airport by August 1996". External communications are defined (Federal Airports Corporation, 1996, p 23) as: "receiving and documenting complaints from members of the public[1] and responding to requests from the community and from regulatory authorities...and in informing the local community of environmental issues relating to airport operations and of the environmental impacts of the airport". Aitken's (1994) review of the public involvement literature concludes that the process cannot rely upon heavily prescriptive methodology because every project and every "public" requires a different approach. One area identified for further research is the lack of a dedicated public involvement database for partitioners and other interested parties to draw upon that contains information about the experiences of others in "analogous situations".

The Draft Noise Management and Air Quality Management Plans (Mitchell McCotter, 1994 a,b) were released in June 1994 to provide a focus for public consideration and comment. They were displayed in local council chambers and at other locations. These drafts had not been endorsed by any of the organisations to whom members of the Steering Committee and working groups belong. The Foreword invited "all members of the public and institutions, particularly those living or located in noise-affected areas, are encouraged to make their views known. A toll free number was provided to allow the public to ask questions or discuss any of the issues. The close of written submissions to be consultants was 12 August, 1994. The views of the Community Advisory Committee and the Australian Air Transport Association (AATA) - which were both prepared without having had the opportunity of seeing the draft plans - are contained in  Sydney (Kingsford Smith) Airport Draft Noise Management Plan (Mitchell McCotter, 1994c, Chapter 11) and Sydney (Kingsford Smith) Airport Draft Air Quality Management Plan Volume 2 - Technical Report  (Mitchell McCotter, 1994d). A Ministerial direction to the Steering Committee to accelerate the development of the plans because of earlier (November 1994) than planned (June 1995) opening of the third runway severely compromised the ability of these two organisations to make

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1  These functions were transferred to Airservices Australia in 1996.

an effective contribution to the public debate. Community outrage prompted an Inquiry into Aircraft Noise in Sydney (Commonwealth of Australia, 1995).

Sydney (Kingsford Smith) Airport now competes with other Australian airports under the new privatisation arrangements. Clearly, these new institutional arrangements pose a threat to its business environment. After a period of reaction to the political and community issues arising from aircraft noise and the third runway (and political intervention to share the aircraft noise with operational plans for rotating the use of all three runways) Sydney Airport has become more pro-active with its public relations campaigns and communication strategies. By early 1998, an internal working document for a business plan (1997/1998) had been developed specifying initiatives, performance indicators and milestones. Restructuring of the Public Affairs section started in August 1997 with managers responsible for corporate relations and for community relations. A public affairs strategy for 1997-1998 had also been formulated with inter-relationships between corporate goals, communication objectives and critical success factors.

## 6. Organisational Change

One overriding, and somewhat obvious, observation from these interviews is that airport ownership and management, the current airport development context and previous local history taken together influence activities being undertaken in the arena of stakeholder involvement, community participation and communication strategies. Notwithstanding the uniqueness of individual airports the aim of analysis in a benchmarking study is to draw out examples of best practice and suggest organisational changes to implement the recommendations.

In order to do this research was also conducted into the theory of policy-making processes, into community participation and into excellence in public relations and communication management, which resulted in a framework for the classification of individual projects. Policy processes have been described elsewhere (Black, 1997): (a) political - rational; (b) bureaucratic as legal; (c) techno - rational; (d) semi - judicial; and (e) consultative. Consultative processes may be sub-divided into three related processes (corporatist, bargaining and pluralist). For each of the five characterisations of the policy process there are typical communication strategies. Governments and airport managers must work with other groups: in a democratic society they need the support of the people whom they serve, and, in turn, the people need the services provided by the government. The process of policy formulation involves the transformation of societal problems, visions and ideas and political pressures into policy and its administration.

However, management provides the key to the type of communications allowed. The culture of the dominant group will determine whether an asymmetrical or a symmetrical approach to communications is taken. Asymmetrical communications (Grunig and White, 1992, p. 43) are more likely to occur under politico-rational, bureaucratic-legal and techno-rational modes of policy process. Organisations are managed as autocracies with power concentrated in the hands of top managers. Leaders know best - they have more knowledge than members of the public. Group members are "inward looking" and do not see the organisation as outsiders see it; information flows out, not in. Efficiency and cost control dominates over innovation.

For consultative processes airport management must embrace two-way communication models. Excellence in public relations based on symmetrical communications is achieved when it is an integral part of group's strategic management process and when public relations identifies stakeholder categories and resolves issues through symmetrical communication programs early in the development of issues (Grunig and Repper, 1992). San Franciso International Airport and Portland International Airport would be a good examples drawn from those Northern American airports in this study. Top management plays a determining role in the way an organisation practices its

communication business. The general public is of no relevance to organisations. Nor do organisations have resources to establish and maintain credible relationships with all peoples and all other organisations. Publics are defined by their connection to an organisation in a particular situation - a specific airport policy, program or project. The dominant coalition determines culture, communication philosophy and public relations approaches, recognise publics, choose interdependencies and position the placement of communication functions in the organisation.

Corporate communications can thus be arranged along a continuum from propaganda (the press agency model), strategies of airport managers; journalism (public information model) through to a two-way symmetric model (Grunig and Grunig, 1992, pp. 286-290). There is a nexus between communication strategies, public involvement in the planning and policy process, and the characteristic type of policy process. The consultative form of policy process should encourage a symmetric communication model. In a two-way communication between top management and publics it is the public who should "be just as likely to persuade the organisation's management to change attitudes or behaviour as the organisation is likely to change the publics' attitudes or behaviour" (Dozier and Ehling, 1992, p. 177).

Measuring the effectiveness of public involvement programs and their associated communication strategies is a crucial area of airport performance which needs to be addressed. Of great practical importance is an identification of the possible consequences of public relations programs. What kind of impacts can they exert on awareness (the message), cognitions (knowledge), attitudes and behaviour? Dozier and Ehling (1992, p. 163), note that many practitioners invoke a "strong effects" view of communication with a domino model implying strong casual links in a chain from message to receiver that has an immediate impact on knowledge, attitudes and behaviour. However, the evidence suggests that there are no powerful tools for impacting publics, especially if mass-mediated messages are primary to the communications program. Cognitive effects have been identified but behavioural effects are relatively difficult to achieve. Dozier and Repper (1992, Fig 8.4, p. 190) have summarised impacts, in categories that are increasingly difficult to achieve, as: the number who learn the message content or increase knowledge, awareness understanding; the number who change opinions; the number who change attitudes; the number who behave in a desired fashion; the number who repeat desired behaviour; the goal achieved or the problem solved; and social and cultural change. Surveys of publics are standard tools of public relations program evaluation, and many airport managers adopt these techniques. Many public relations experts interviewed recognise the importance of measuring effectiveness (see, Lach and Hixson, 1996).

Eight design principles for airport owners and manager for institutional re-engineering which fortify the logic of collective action, can be drawn selectively from Ostrom's study of natural resource systems (Ostrom, 1990, pp.88-102). One, the capacity of participants to design their own institutions should not be overruled by external government authorities. Two, the core task of design is to deal with circumstances of an uncertain and complex environment. Three, institutional design should be framed in a manner consistent with practical, local conditions. Four, the boundaries of the "common" must be clearly defined, both in terms of access rights and the characteristics of the pooled resources. Five, institutions need to create extensive norms among participants which help to define proper behaviour that fosters interdependence and long-term trust. Six, individuals affected by the operational rules should be able to participate in modifying the rules. Seven, those who are assessed as violating the operational rules should be subjected to a graduated scale of sanctions. Eight, low-cost mechanisms should be available for conflict resolution.

Corporate transformations to position the business of communications can be successfully managed but there is no single path to change implementation valid for all situations (Stace and Dunphy, 1994, p.93). Successful organisations use a blend of styles internally, dominantly alternating between consultative and directive, and vice

versa. Based on the style of change management (collaborative, consultative, directive and coercive) and the scale of change (fine-tuning, incremental adjustment, modular transformation and corporate transformation) Stace and Dunphy have found successful Australian organisations have adopted one of four approaches to corporate change: developmental transitions; task focused transitions; charismatic transformations; and turnarounds.

Any suggestion as to which approach is suitable for corporate change in the management of Australian airports requires linking four generic types of business strategy (Stace and Dunphy, 1994, Table 4.1 - 4.4, pp 107-110) with the types of change identified above. Give the Federal Governments policy of airport privatisation and the sale of the former Federal Airports Corporation's major airports, the business environment has changed dramatically to one of competition so that the theoretical business strategy dictates a turnaround to reposition the organisation. There needs to be a refocus on the core business and selected business areas to realign the airport with both its competitive environment and the constraints to growth that could be imposed by the social and environmental impacts of its operations on neighbouring communities. The major focus is on creating a new corporate plan and negotiating it with external stakeholders. The emphasis is on breaking the old frame (FAC airport) to create a new structure. To do this, for example, the eight-stage change process advocated by Kotter (1996) can be deployed whilst recognising that effective change requires "a well-orchestrated, integrated design that responds to needs for learning, realignment, negotiation, and grieving", (Bolman and Deal, 1997, p.339). These "soft" aspects - the human elements of change - are covered in a "how-to" manual by Galpin (1996).

## 7.    Conclusions

The problem of how to develop better procedures for communications and effective community involvement at Sydney (Kingsford Smith) Airport was suggested by the Federal Airports Corporation (FAC) as a topic being one of the crucial areas of organisational performance. Experience from the environmental impact assessment of Sydney Airport's third runway and two possible sites for a second airport and the development of the noise management and air quality management plans from 1992 to 1994 all require reflection and consolidation as important case studies of Australian airport planning . More effective communications strategies and stakeholder (interest group)/community involvement procedures need to be proposed for implementation and this can be greatly assisted through benchmarking studies. As the author was elected by a Community Advisory Committee in 1992 as its Independent Convenor Committee on environmental management plans, he is well positioned to analyse some aspects of communication strategies and community involvement at Sydney (Kingsford Smith) Airport and other airports.

Airport owners are confronted with community involvement when proposals are made to expand facilities at existing aerodromes or investigations are undertaken to find the sites for new airports and to develop them. In the context of environmental impact assessment (EIA) "public participation" is the involvement of members of the community in decision-making - which can take many forms - and derives from a legal right to participate at particular stages of an EIA process, or from invited opportunities to participate where the owner is pro-active. In addition, airport owners must consult with a range of key stakeholders in undertaking their business effectively and may wish to involve the broad community - for example, procedures as part of well formulated communication strategies or environmental management systems (EMS). Therefore, this paper has concentrated on the process of benchmarking and the policy context of the problem of participation and communications facing the Australian Federal Airports Corporation and other owners of Australia's privatised airports. Corporate commitment to community involvement ranges from a defining element of an organisation's operations through to implicit recognition that some form of community involvement, over and above any statutory requirement, is consistent with good business behaviour. A rigorous classification of examples of communication strategies at major airports, and

measures of effectiveness for public involvement ( Lach and Hixson 1996), are obvious directions for this research.

When expanding this research into organisational change and airport performance, another important direction will be to obtain other perspectives on communication processes and community involvement. Opponents of airport development projects are only a loosely confederated group. While such groups in the United States frequently share experiences through specialised trade publications, such as *Airport Noise Report*, there are only two national organisations which have focussed attention on airport development issues from a community perspective. The National Organisation to Ensure a Sound-Controlled Environment (NOISE) represents local governments affected by airport noise and the National Airport Watch Group (NAWG) represents some local governments but primarily grassroots citizens organisations on the same issues. Neither organisation has developed a national constituency to compare to those organised by the American Association of Airport Executives (AAAE) or the Airports Council International - North America (ACI-NA), the two principal airport industry groups. By tapping into grass - roots organisations a balance of opinion should be collected to those obtained from the airport industry on the effectiveness of communications and public involvement. Reference to the Community Advisory Committee and environmental management plans at Sydney (Kingsford Smith) airport and their views, as discussed in Black (1997), is an example of this line of research investigation.

## Acknowledgments

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# AIRPORT PLANNING AND LOCATION

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## 1. Introduction

Geographers have long been attempting to discover the spatial regularities of economic development. A critical factor in this process has been the improvement of spatial interaction through the development of transportation systems. From its beginning metropolitan transportation development has been a continuous process of spatial diffusion but also a sporadic process influenced by many specific forces: economic, social and political (Taaffe, Morrill and Gould 1963). Whereas the historical development of maritime and land transport has been well documented in numerous studies (Gauthier 1970; Rimmer 1973; Hoyle 1973; Taaffe, Gauthier and O'Kelly 1996), the evolution of air transport has more often been treated separately or on the basis of interregional relationships.

From a historical perspective most large metropolitan concentrations owe their existence to water and rail transportation. Air transport has now replaced maritime transport and railways as the basis for trade, technological transfer and economic growth. For example, a city would likely be built next to a natural harbor. As the city spread out in all directions from this original center, the core would become the central business district (CBD). As activities in the CBD and in the harbor increased, their competing claims for land would inevitably conflict. Large ships and faster turnaround capabilities have greatly reduced the number of ships and the length of berth required to handle a given tonnage, but they have also increased the need for a large area behind the berth for handling the tonnage by rail and road. Thus, relocation of the port to new land becomes unavoidable (Taylor 1966, Bird 1971, Lawrence 1972, Karmon 1980). Each new type of long-distance transportation has repeated this pattern.

Railway, bus and airline termini have historically been located as close as possible to the city center—usually without much opposition from the public. Yet as the cities grew and the volume of transport increased, conflict inevitably arose (Blumenfeld 1967), resulting in a continuing outward migration of airport land use. Kirchherr (1983) reported about this process in the Chicago region. In 1941, 74 percent of that region's airports were located within 50 kilometers of downtown Chicago. By 1975, only 46 percent of the airports were sited in the same area.

Although airports are a recent technology and thus have a weaker historical linkage when compared to seaports or railway stations, they nevertheless pose by far the greatest problem. This is because of their very size, the impossibility of obstructing runways by viaducts or placing them underground and the extension of their approach and flight paths far beyond their actual zoning boundaries. Nevertheless, most cities appear to be determined to site airports as close to their centers as landside requirements, such as open fields, permit. This repeats on a much larger scale the barriers to future urban growth that we have already experienced with railway facilities and also creates obstacles to the future extension of airports.

Airports represent large land uses in cities and have become both functionally and symbolically important to the welfare of cities. However, airports have become one of the least understood elements of the metropolitan transportation system (Kirchherr 1983). Little attention has been given to the impact that airports have on local and metropolitan development. Hartshorn and Muller (1989) included Atlanta Hartsfield International Airport

as one of several diversified centers of economic activity in the suburbs. In the generalized layout of the urban realms model developed by Vance (1964), airports are seen as fairly recent transportation systems, which had little effect if any on the development of large metropolitan areas. In many cities, airports were not even a fully connected member of the transportation system. The urban realms model represents the transition from the single-centered to the polycentric city (Hartshorn 1980). It submitted an alternative to core-periphery models of intra-metropolitan growth and transportation development by introducing self-sufficient suburbs. Unlike the evolving technology and network-expansion process of the transportation-related eras (Adams 1970), airport development was not necessarily dependent on past transportation technology. Therefore, airport location could be determined in many cases more on the needs of the airport (i.e., private flying), than on the needs of competing or complementary modes of transport. That is not to say that airports are not accessed by other transport technology, but the decision about where to locate airports is only partially dependent on the existence of other transportation linkages.

Technological improvements have provided the impetus for airports to expand in order to upgrade their runways or add new facilities. This occurred with the advent of the new jet aircraft in the 1960s and again when larger and more sophisticated aircraft such as the Boeing 747 were introduced into service in the 1970s. Many cities welcomed their airport expansion plans, believing expansion would facilitate the city's economic growth. As a result, competition among airports for a larger share of the aviation market increased significantly. Wanting to lure more and more traffic by dominating competitive markets, many airport authorities tended to overestimate potential demand and built to accommodate their overestimations.

Although airports are not considered part of urban transportation development, airports did affect metropolitan structure through their land and airside physical characteristics. They did not alter metropolitan structure through the mass use of private aircraft, as Isard and Isard (1945) had predicted. They stated that "it seems reasonable to predict, very roughly, that within a quarter of a century following the close of hostilities, private aircraft will be utilized as extensively as was the automobile in recent prewar years. ... Through increased population mobility and diminished time dimension of distance, aircraft should enlarge the potential consumer hinterlands of urban centers, and thereby lead to great size differentiation and selectivity" (pp. 157, 162).

Nevertheless, the planners *did* make provisions for airports and their complementary activities (Hoover 1963). The aim of this paper is to examine the sequence of metropolitan transportation development in order to take into account the effect of airport location. I will attempt to show that, although airport location seems to have the fewest physical restraints (because airports can be located on practically any level field), when compared with traditional metropolitan transport such as seaports or railway stations, the demand for air transport has greatly influenced airport location. Thus, airports have almost always been located as close as possible to city centers, but on the outskirts of the urban area. The close-in airports of today were originally located on the fringe of the cities in earlier eras. It is the cities themselves that have grown outward and, in some cases, people have attempted to have airports relocated farther away. As urban populations have increased, so has the demand for air transport and, hence, airport size and associated activities. This has resulted, however, in a growing conflict between airports and cities.

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## 2. Airport Planning and Location

International air transport has grown at a phenomenal rate since the first scheduled air service was established following World War I. The enormous change is evident when one views the developments that have taken place in aviation since the beginning of regular service in the 1920s, when there were only a few thousand passengers. Jet aircraft were first introduced in 1958, and today over a billion passengers take domestic and international flights every year. The physical aspect of airports has also changed enormously, owing to the increased demand for air transport and to the many technological changes that have occurred in the aviation industry. This has increased the number of aircraft movements as well as the number of larger aircraft that operate from most international airports. The infrastructure of the post–World War I era comprised mostly airfields operated by the military and postal authorities, whereas airports developed much wider roles and responsibilities in the post–World War II era. Nowadays airports are of crucial importance to the nations and communities that they serve (O'Connor 1989, Taneja 1987, Pryke 1986, Gidwitz 1980).

Many of the problems associated with airport location can be avoided by identifying the most functional airport community that would be compatible with its neighbors (Conway 1980). This is not by any means to suggest that homes be built for people with hearing disabilities in the noise-polluted neighborhoods around local airports. Some planners have argued that it would be a better solution to build airports inside urban areas, considering the higher tolerance of urban residents to noise and the existing infrastructure (Buchanan 1981). We believe it would be preferable to attract less noise-sensitive land uses, such as industrial parks, to the airport environment. Such land uses can serve as a barrier against residential sprawl and also as a potential area for future airport expansion.

Most existing older airports are situated relatively close to city centers, which over the years have spread out to the immediate airport environment. Such airports have limited expansion possibilities because of the dense urban surroundings. They frequently benefit, however, from relatively efficient public transportation that has developed along with the expansion of the city. Some people may view a central airport location as a disadvantage because of the resulting congested access roads and the age of the existing public transport service. On the other hand, empty land suitable for building a new airport on is generally located far from town centers and would require not only the cost of building the airport itself but also the costs of building access roads and providing public transportation to the new site.

Airport location poses a planners' dilemma: whether to place the airport near the city for convenient access, with the negative side effects of noise and pollution, or to place the airport far away from the city, with an advantage of low-cost land, but at the cost of poor access, which would require investment in access routes. In the past, researchers have shown that conventional transportation methods (i.e., bus, car, rail) are the *only* options worth considering to solve the access problem (Lawrence 1970; Witheford 1969), because innovative methods such as the monorail or other high-speed transport systems have proven too costly (Walters 1978). The conclusion appears to be that the closer the airport is to the conventional network (i.e., highway) the better. However, the real issue is not about conventional versus innovative methods, but about multimodal accessibility and intermodal

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connectivity. The large European hubs, such as London Heathrow (24 kilometers from the city center), Frankfurt Main (9 km), Paris Charles de Gaulle (26 km) and Amsterdam Schiphol (15 km) are well connected to several different transportation networks on different geographical scales. The degree and type of connections available are more important than the distance an airport may be from the city center. For example. Haneda International Airport is 19 kilometers from Tokyo's CBD and travelers can choose between rail or road connections. Travel to Haneda takes only 20 minutes from Tokyo's CBD by rail, whereas. although it is the same distance from the Tel Aviv CBD to Ben-Gurion Airport. travel. which is possible only by road, takes 10 minutes longer, and this can vary. depending on traffic congestion.

Increasing ecological awareness and attention to environmental amenities among all levels of the population have had a substantial impact on airport development (Neales 1972; Horenjeff and McKelvey 1983; Ashford, Stanton and Moore 1984; Wells 1992). Although most people will object to having an airport near their homes, no matter how little effect it may have on the whole metropolitan community, it should be remembered that airports also create expectations for land-use development. In spite of favorable citizen support. anticipated development may never materialize. Young and Schoolmaster (1985) reported that the Euless municipality, for example. did not enjoy any land-use development following the opening of the Dallas-Fort Worth Airport in 1972, whereas other municipalities reported significant increases in commercial and residential land uses. The decision to build a new airport. usually in relatively remote areas, creates expectations of new zoning and potential economic development of the periphery. Relocation of airports frees expensive land and may enable increased concentration as a result of taller buildings.

It is no longer possible to build new airports or expand existing ones on the basis of market need or technical and design considerations alone. Airport planning is nowadays subject to environmental and political constraints that reflect the development of the air transport industry. Many cities, such as Dallas-Fort Worth, are demanding a say in the land use control of airports through zoning ordinances (Cole 1993). This type of planning is a very complex activity that encompasses a variety of processes, participants and results, and in which every stage is connected to a political system and hierarchical levels of political power. These procedures may be an extension of existing processes or completely new processes of redevelopment. The participants or actors are the national government. local government, local communities, airlines, developers and international organizations. Each "actor" exerts his own political power at a different level, which creates an overlapping system of powers, which all often act together against the advice of authorities, actual national needs or even relevant expertise.

It is far more desirable to anticipate increasing traffic demand (which may never actually come to pass) than to face impending growth without sufficient resources to meet the increased demand upon the infrastructure. As a result. it has been found that, in many cases. the actors have overestimated their needs for airport development. A good example of this is Mirabel Airport in Montreal, which was planned in the 1960s to cater to technological changes in aviation and to meet the increased passenger and freight demands in Canada. It was opened in 1975. The dimensions othe plan were immense: The Canadian government acquired 22 square kilometers of land, and the facility was designed for the next century—large enough to accommodate all future developments, such as the demand of

super jet planes. Mirabel was designed as the largest airport in the world at the time. At the same time, however, Montreal's influence declined as compared with Toronto's, and this reduced its importance in the Canadian context (Feldman and Milch 1983). Paradoxically, even today Montreal's old airport—Dorval—can very easily handle the air traffic into and out of Montreal and since 1995 has handled practically all of the traffic.

Closer-in airports do have local advantages, but they also have capacity constraints, which result in the decision to build new airports farther out. Montreal Mirabel is an example of an airport that was built too far away (60 kilometers) from the city center, and demand did not materialize. In 1996, Mirabel was handling only 18 percent of Montreal's passenger traffic. Conversely, Washington D.C.'s Dulles Airport was originally thought to have been built too far away (42 km) from the capital's downtown, but, in 1996, was handling a sizable proportion (47 percent) of the area's passenger traffic, and it handled most (88 percent) international flights.

When air transport increases significantly every year, three options are available for providing a similar increase in airport capacity. The first is building additional airports as was done in the cases of London's Stansted in 1970 and Chicago's O'Hare in 1962. This option always involves community resistance, as was the case with London's third international airport—Stansted (Buchanan 1981, Farrington 1988). The second option is to accommodate the growing traffic in the existing international airport, which is usually accompanied by increasing environmental and community concerns, as was the case with Boston's Logan Airport (Nelkin 1974), which is located only 6 kilometers from the CBD. These two options can become the center of debate, as happened during the discussion of Sydney's twenty-year future airport needs. Throughout that period, a third runway was strongly advocated by the aviation authorities. However, the critics argued that adverse impact on the surrounding urban area, particularly through exposure to aircraft noise, was already considerable and instead supported the construction of a second airport (Sanders 1989). In 1992 the third runway at Sydney's airport was built.

The third option is to divert traffic to other regions' airports, provided that ground transportation is available to deliver passengers to their final destinations. Airports, as suggested by Walters (1978), serve as a kind of national monument and lack the usual expenditure restraints, because they are usually publicly owned and operated. As a result we find more airport authorities investing in expanded and new infrastructures. Interurban competition over public airports for the purposes of economic development includes incentive packages that are designed to attract airline capital. In 1995, the campaigns for American Airlines' and United Airlines' maintenance operating centers involved Dallas versus Oklahoma City airports for the former airline, and Denver, Indianapolis, Louisville and Oklahoma City, for the latter (Nunn et al. 1996).

## 3. The Location of World Airports

To evaluate airport location, we primarily used the International Civil Aviation Organization's (ICAO) statistics, and we used airport information services to collect annual traffic statistics and historical data from 167 countries. In 1996 there were over 100,000 airports in the world, which were used by both scheduled and chartered flights. All catered

to over 2 billion passengers. The United States had the largest number of airports, with close to 15,000 private and public airports operating in 1996. Smaller countries and island states would naturally possess only a few airports because of their limited size and the large area of land required on which to build an airport. For this reason we find more airports built on artificial islands in dense island states such as Hong Kong and Japan. International disparity could also be found by comparing airport activity. In 1996, O'Hare Airport in Chicago was the busiest airport in the world, catering to over 67 million passenger movements. Heathrow in London was the busiest international airport, with close to 47 million passenger movements. Memphis was the leading freight and mail airport, moving over 1.7 million tons.

The major world airports were built in three distinct eras, as identified in Figure 1. The first era was typified by rapid development from the beginning of air service following World War I up to the mid-1950s, with some decline during World War II. During that period almost 2.5 new international airports were built every year. Air service during that time grew tremendously, from 65 billion passenger-kilometers in 1955 to 1,142 billion passenger-kilometers in 1982. The second era, between the mid-1950s until the beginning of the 1980s, was a period of extended service and limited building of new airports—usually second and third metropolitan airports were built to relieve congestion at the older site. For example, Chicago O'Hare was opened in 1962, Kiev Borispal, in 1966 and Paris Charles de Gaulle, in 1974. During that period, fewer than one international airport was built each year. The third era began in the early 1980s and continues today. It is characterized by the building of very few, if any, new airports. On average during this period, one airport has been built every three years. When new airports were built, it was in order to resolve environmental conflicts arising from the location of the older airports close to populated areas. For example, Kansai International Airport was built on artificial islands in Osaka Bay 40 kilometers from downtown Osaka, and it was opened in 1995 to replace Itami Airport, which is only 16 kilometers from the city center and within a growing urban area.

From a chronological perspective, the location of 80 percent of all airports was determined before the introduction of jet airplanes in 1958. Most airports were built during the two world wars for military use and were converted afterward to civilian use. Heathrow in London, for example, was built in order to serve the troops in the Pacific Theater. Although located only 24 kilometers from central London and within a densely populated area, it still accounts for about 80 percent of the total flight movements of the four greater London airports, in spite of the fact that relief airports are available. This brings up the question of whether London's residents are so tolerant of Heathrow or whether air transport demand is seriously affected by airport location.

Our data indicate that the average distance of airports from their city centers is 17.6 kilometers. Over half of the airports are located within a distance of 10 to 30 kilometers from the CBD. Only 10 percent of the airports are located extremely close to (less than 5 kilometers) or extremely far from (over 50 kilometers) the CBD. This situation is a compromise between locating airports in remote versus close-in sites. Remote airports tend to result in decreases in demand. The effect of airport location on demand for domestic flights is illustrated in Figure 2. The regression model provides a good explanation (R square equal 43 percent), with significant results. In order to isolate the airport location

effect we included only competing airports in regions where more than one airport existed. The demand side was analyzed using traffic data for domestic flights only, since the demand for long-haul service, which consists of mostly international flights, is considered inelastic Deganis (1992). We also wanted to reduce shifts in demand resulting from political decisions and regulations. In most closer-in airports, flights are regulated and have slot constraints and night curfews. Government regulators, for example, forced charter airlines out of Heathrow in London and forced most foreign airlines tland in Charles de Gaulle Airport in Paris, 26 kilometers from the CBD, which is 14 kilometers farther from the CBD than Orly—the older airport in Paris. The model show that increasing the airport distance from the CBD decreases air traffic demand. Table 1 presents the declining market share of domestic passenger traffic at competing metropolitan airports. Closer-in airports are located an average of 13.6 kilometers from the CBD, whereas second and more remote airports at each metropolitan area are located an average of 42.6 kilometers from the CBD. It is also evident from Table 1, that on average, the closer-in airports receive a larger share of the market. Seventy-one percent of the traffic passes through closer-in airports, whereas only 29 percent of the traffic goes through the second and more remote airports. It appears that, in a competing environment, airports close to the city center are more attractive to passengers and airlines, and remote airports tend to show a decrease in demand.

The demand side advantage of airport location can bring one to the conclusion that in order to increase passenger demand, airport location should be as close as possible to the CBD. However, the data indicate that airports, such as Haneda-Tokyo, although located relatively far away from the CBD (19 kilometers) can maintain a relatively high share of the market (97 percent)—approximately the same market share realized by Aeroparque Jorge Newbery-Buenos Aires, which is located only 8 kilometers away from the CBD. That leads to the conclusion that the effect of airport location on demand is a function of the absolute location of the airport in relation to the CBD and the relative distance between the competing airports. In a competing airport environment, the market share of the first and closer-in airport will decrease as its location gets farther away (relative to the computed average of 13.6 kilometers) and as the second airport gets closer-in (relative to the computed average of 42.6 kilometers).

The economic benefits of close-to-city-center airports in terms of increasing the potential number of passengers using air transport is evident from the data. However, airports extremely close to city centers have severe limits on airport activity, entail environmental pollution (noise and air) and result in limitations on building height. We computed the average size of international airports to extend over 14.7 square kilometers of land. The largest airports, such as Denver International, use over 54 square kilometers of land. More efficient airports, such as Macau International, which extends over only 3.5 square kilometers, can be found in small island states. It is practically impossible to find large segments of vacant land near the center of large metropolitan areas that do not pose an environmental threat to large populations. This is why the recently planned airports of Chicago and Los Angeles and the newly opened airport of Seoul are some 50-plus kilometers away from the CBDs. One way of resolving this problem is to build artificial islands off the coast, such as was done at Kansai International Airport, which is still relatively far away (40 kilometers) from Osaka's business center.

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Efforts to build more remote airports are shown in Figure 3. Most cities are served by only one airport. The second, third or even fourth airports were usually built at a greater distance from the CBDs, since suitable land for new airports was more difficult to find in large metropolitan regions. For example, Stansted, built in 1970 as London's third international airport, is 55 kilometers from the CBD. Mirabel opened in 1975 and is 60 kilometers from Montreal's CBD. Narita opened in 1978 and is 65 kilometers from Tokyo's CBD. And Munich II opened in 1992 and is 57 kilometers from the CBD. Since airport location has had to adjust to growing urban areas, we might expect to find more remote airports in larger metropolitan areas in the future. Many older airports *do* survive the environmental pressure of large metropolitan areas and maintain their location close to the CBD. The airports listed above demonstrate that, on its own, a new airport is not sufficient to close down an older airport and that the demand for a nearby location ensures continued operation and even redevelopment of the older airport.


4. The Story of Airport Location and Development

The story of airport location and development begins when the first airports were sited on level fields near urban areas. This was true in the 1920s and 1930s when the sites of many present airports were first determined. Some of them began operating on grass fields, as was the case with La Guardia Airport in New York in 1933. In 1939, its runway was the first to be paved in North America. In the late 1940s and the early 1950s the airlines entered the mass travel market, and low fares encouraged a phenomenally growing demand. The runways were extended to allow for larger and heavier aircraft, such as the DC-3, and later the four-engine DC-4, DC-6 and Constellation aircraft. New termini were built that included improved passenger amenities. This was done by United's predecessor for its passengers along the Overland Trunkline route from New York to California.

On the ground, however, the airports became a barrier to the development of residential neighborhoods and were limiting the development of urban areas. As a result some cities were forced to grow away from the airports. For example, Tel Aviv's metropolitan expansion to the east and south was restricted by Ben-Gurion International Airport's approach path, and for many years new housing units were only built to the north of the CBD. As a result of building-height restrictions, the area around the airport contained many vacant, low-rent lands that became very attractive for commercial use.

Urban development and technological improvements are usually reflected—with a greater or lesser time lag—in a new infrastructure design. It is also true that the location of transportation infrastructures, such as airports, can divert traffic from other means of transport and can become a focal point for other economic activities. For example, the relocation of the Paris wholesale market from Les Halles in the downtown area to Rungis-Halles near Orly Airport happened, among other reasons, because of the available vacant land near the airport and the convenient location for air shipping of some of the products.

In the late 1950s, jet aircraft were first introduced into the fleets of commercial air carriers. Airports needed to provide longer, more stable runways for the heavier aircraft and faced adverse community reactions to the intrusion of jet aircraft noise. This lead to a redesign of certain aspects of the basic airport plan. The jet airplane not only increased airport

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capacity, it also forced designers to rethink the old tri-runway system, which was designed to enable planes to land in wind from any direction. Longer, open "V"-shaped or parallel runways replaced the old runways. However, aviation and airport planners were caught unaware by the rapid growth in passenger and aircraft movement numbers that occurred during the 1960s (De Neufville 1976). In the decade from 1960 to 1969, world passenger movement virtually trebled, from about 100 million to over 300 million passengers annually (ICAO 1970). In order to make up for the deficiencies of previous years, there was a clear need for major expansions of airport facilities. Second, third and even fourth airports were built in Montreal, London and New York. The new airports were immense and were supposed to cater to all foreseeable growth. It was often necessary to locate such airports in remote rural areas quite far from the CBD. Some airports were built as relief sites to replace old historic airports, but newer, more modern remote airports were not built in all places, and most places choose not to close down old airport facilities. London City Airport is one example of the importance that is placed on closer-in airports. In order to use the competitive advantage of the airport location 5 kilometers from the CBD, in 19, Air France was operating 25 weekly flights from London City Airport to Orly but only 15 weekly flights between Heathrow and Orly.

Often there was more pressure to keep the old airports open than to close them, thus creating conflicting goals within communities. There was criticism over the inefficiency of a dual operation, and the communities were split between those who favored the convenience of airports close to city centers and those who wanted to lessen the environmental impact. One way of resolving this conflict was through a functional division of the airport system. The old historic airport was used for specific demand services, such as business travel and short-haul flights. Short take-off and landing (STOL) airports can remain in close proximity to urban activity without generating too much conflict with their environment because of quieter engines and small aircraft. The more distant, larger airports can serve as international gateways, where large wide-bodied aircraft can land with little impact on the environment and service can be offered twenty-four hours a day. STOL airports can also free up restricted land along the approach path, which can be redeveloped for low-density residential and commercial activities.

Are we entering a new era where aviation, international markets and time-based competition will predominate new economic growth nodes, with airports as locations of competitive advantage and as primary job and wealth generators? The idea of the global transportation park in North Carolina, proposed by Kasarda (1996), is based on this new era. It would be located at an underutilized and relatively remote airport 130 kilometers from North Carolina's Research Triangle Park, but with intermodal connections, where over 15,000 contiguous acres of surrounding land would serve as an integrated industrial and commercial site. The idea was ushered in by large high-speed airplanes, advance telecommunications technologies and three intractable forces: the globalization of business transactions, the shift to just-in-time manufacturing and inventory control methods and the growing need of export industries to ship products quickly by air to distant customers.

## 5. Conclusions

Contemporary urban design has made provision for airports and their complementary activities. Airports have always been sited close to or within easy access to urban areas. Consequently, airports have affected both the structure of urban areas and regional development. In turn, urban land-use allocation and the outline of cities have influenced the location of new airports and the development of existing airfields. Most existing older airports are situated relatively close to city centers in urban areas that have grown over the years to merge with the immediate airport environment. Relief airports can only be located inconveniently far from the city centers and require the provision of intermodal accessibility to the new site. In addition, remote airports tend to decrease demand for air transport. For this reason, taking into account the higher tolerance urban residents have to noise and the fact of existing infrastructures, airports might better be left *inside* urban areas.

Relocating airports from city centers would free expensive land and might enable a higher concentration of buildings to be built in the vacated areas. The relatively small number of cities that built new remote airports to cater to the demand is also a sign that responsiveness to airport demand is much greater than responsiveness to environmental considerations. This brings one to the conclusion that the political power of airports and their activities is much stronger than the power of their opposing communities. As a result, the aviation industry is willing to pay the higher costs of quieter engines and restricted operation hours in order to keep airports close to the city centers. Are we entering a new era where aviation, international markets and time-based competition will predominate the new economic growth nodes, with airports as locations of competitive advantage and as primary job and wealth generators? As yet, very few regions are building new transportation infrastructures to cater to a new wave of economic development.

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Figure 1: Chronological development of airports

Figure 2: Airport demand function

Figure 3: Metropolitan location of Airports

15

Table 1: Airports Locations and Market Share

| City | Airport | Location | | Market Share | |
|---|---|---|---|---|---|
| | | First | Second | First | Second |
| Berlin | TXL | 8 | | 98% | |
| | THF | | 36 | | 2% |
| Buenos Aires | AFP | 8 | | 98% | |
| | EZE | | 51 | | 2% |
| Chicago | MDW | 16 | | 14% | |
| | ORD | | 34 | | 86% |
| Houston | HOU | 16 | | 28% | |
| | IAH | | 32 | | 72% |
| Kiev | IEV | 3 | | 43% | |
| | KBD | | 38 | | 57% |
| London | LHR | 24 | | 77% | |
| | LGW | | 46 | | 18% |
| | STN | | 56 | | 7% |
| Milan | MIL | 10 | | 95% | |
| | MAP | | 46 | | 5% |
| Montreal | YOL | 25 | | 98% | |
| | YMX | | 60 | | 2% |
| New York | LGA | 13 | | 60% | |
| | JFK | | 35 | | 40% |
| Paris | ORY | 14 | | 85% | |
| | CDG | | 26 | | 15% |
| Tokyo | HND | 19 | | 97% | |
| | NRT | | 65 | | 3% |
| Washington | DVA | 7 | | 63% | |
| | DUL | | 42 | | 37% |
| Summary | n=25 | 13.6 | 42.6 | 71% | 29% |

16

Fig. 1

average number of airports built

years

1919 1924 1929 1934 1939 1944 1949 1954 1959 1964 1969 1974 1979 1984 1989 1994 1999

0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00

Fig. 2

Domestic market share vs. Distance from CBD (kilometers)

Y = -0.00134*X+0.87
Rsq=0.433

Fig. 2

percent of all airports

100%  90%  80%  70%  60%  50%  40%  30%  20%  10%  0%

first airport

second airport

distance from CBD

0   5   10   15   20   25   30   35   40   45   50   55   60   65   70
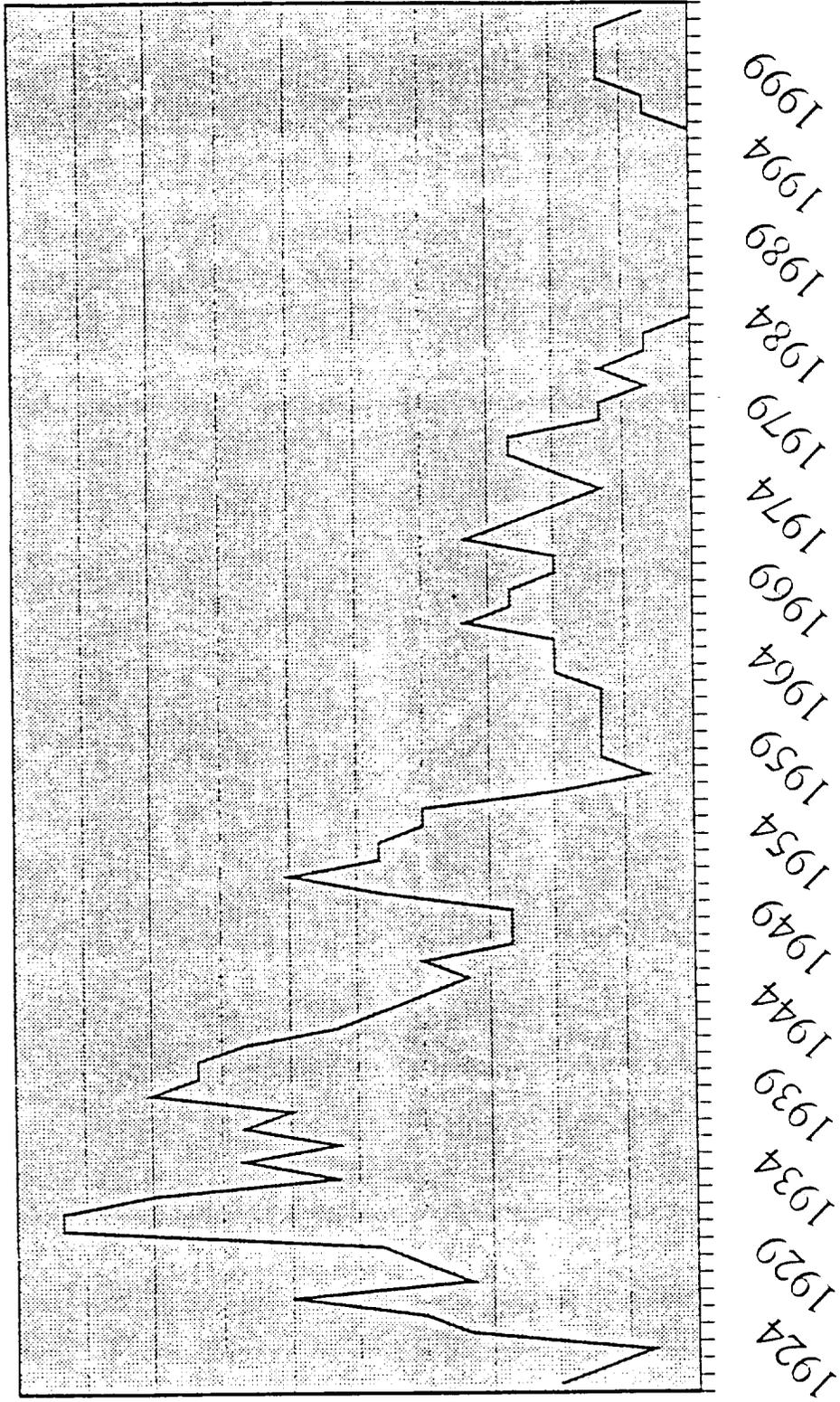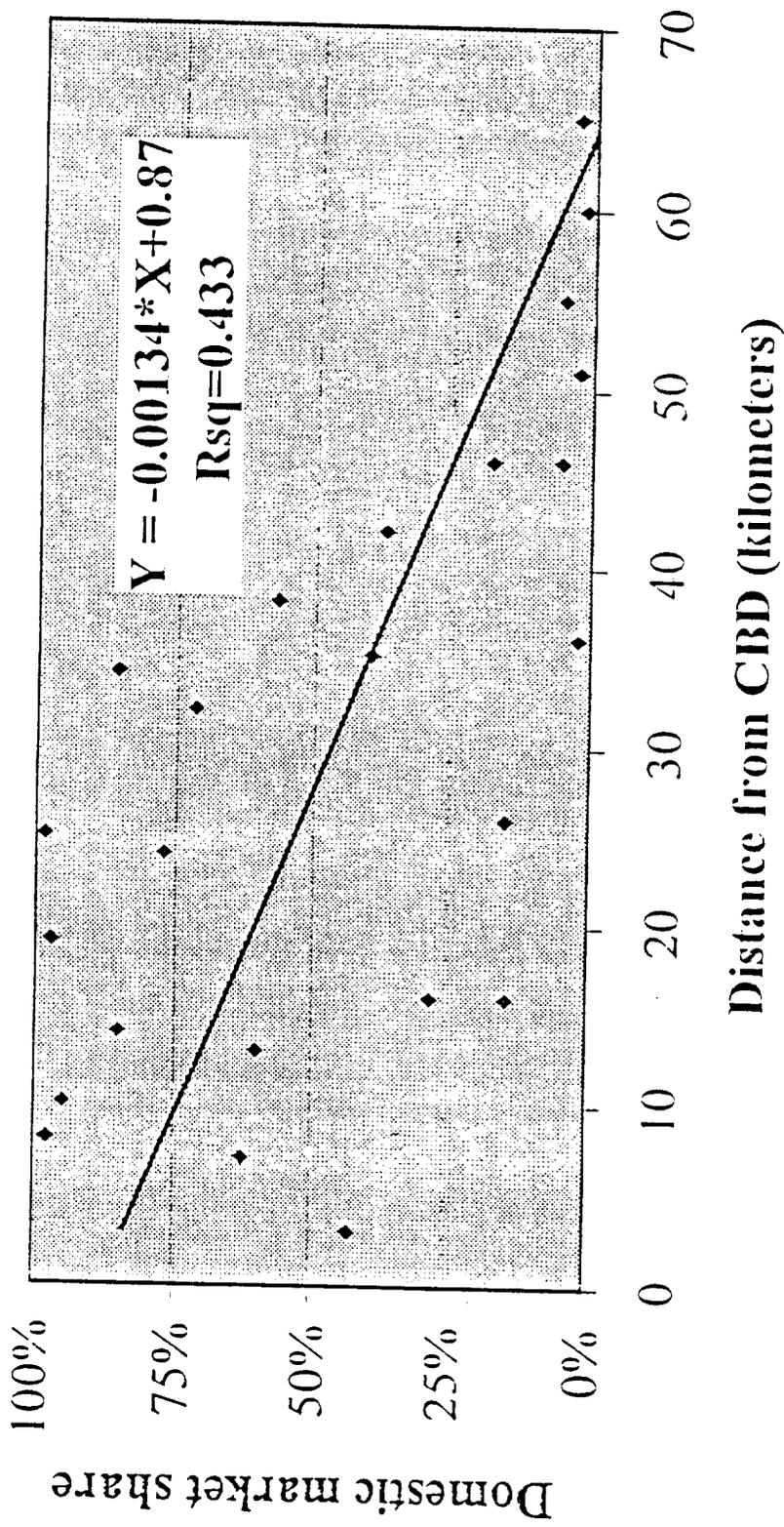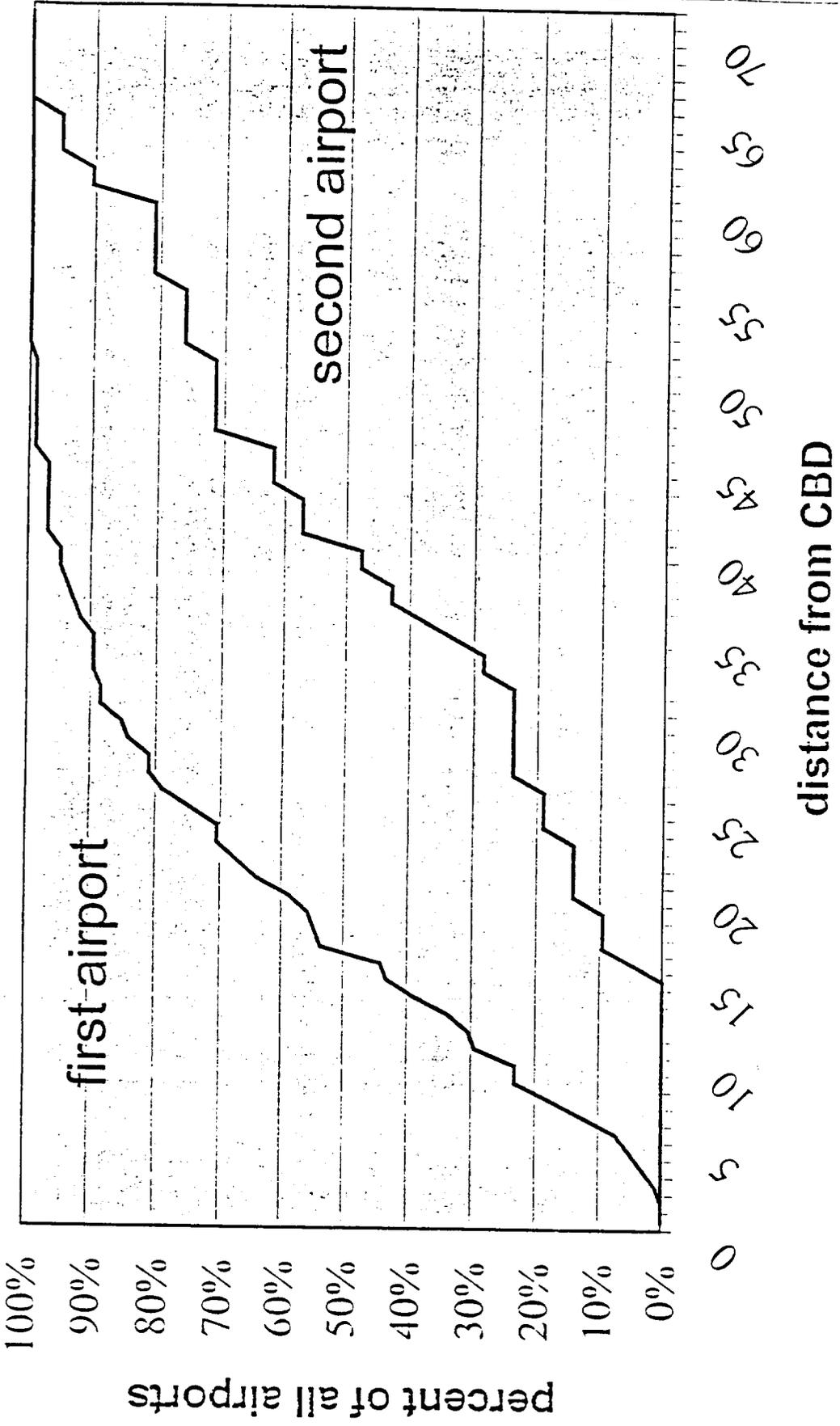
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# LOCATION OF INTERNATIONAL AIRPORT
## AND
### REGIONAL DEVELOPMENT

- SOCIO-ECONOMICAL ANALYSES OF THE PREFERENCES
OF TRAVELERS, AIR TRANSPORT INDUSTRIES AND REGIONS -

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Contents

# 1 INTRODUCTION

The aviation network is largely transforming. In order to cope with the change of the aviation network, what kind of aviation policy is required for each region?

Briefly, the aviation network is transforming as follows:
First, the role of the airport for the development of cities and regions is rapidly growing. Now, airport can be regarded as "Regional Minimum" facilities, that is to say, one of essential infrastructures for the regional development. Airports are the gateway for travelers, the terminal for the high value added freights, and the interchange of information. So, after a series of political and economical change, which include the end or the ease of the Cold War, economic growth especially in East Asia, globalization of economic activities, the role of airports has been enlarged as "Regional Minimum" facilities.

Second, the composition of international aviation network has changed significantly. Three factors, which are rapid increase of demand for air transportation especially in Asia, recent improvement of aircraft' performance and the liberalization, are proceeding simultaneously. Consequently, the international aviation network will become "Best Mixed Network (BMN)". BMN is the network in which the Hub-and-Spoke Network (HAS) and the Direct Flight Network (DFN) are mixed best.

Third, the international aviation fare system is changing greatly. Today, most of local airports in Japan do not have an international direct fare. However, the opportunities for international travelers to arrive or depart to/from local airports will increase the spread of the international direct fare, because of the intensification of competition.

In order to cope with the change of the aviation network, what kind of aviation policy is required for each region? In other words, how to improve international airport in each region? How managed it? In addition, how to use it to activate regional economy and society? Objective criteria and indices are required for this complicated issues.

Figure 1 shows the structure of this paper. In the international aviation market, there are two main actors: travelers and airlines. Therefore, demand of travelers and behavior of airlines decide international air transportation network. International air transportation network influence on regional economy and society. Since airports are becoming "Regional Minimum" facilities, the influence is large. Therefore, actors in the region, such as regional governments, try to make plans to normalize travelers' demand and airlines behavior. In this paper, economical and political proposals are shown.

This paper is composed of five chapters, including this introductory chapter. In chapter 2, the preferable arrangement of international airports in a region based on travelers' demand is examined. In this chapter, the Chugoku-Shikoku region (CS region) in Japan is chosen

Background: World Economy, Politics and so on

Market

Chapter 2

Demand of Travelers

International Air Transport Network

Cost Structure of Airlines

Chapter 3

I N F L U E N C E

Actors in the Region, Regional Government etc.

Influence on Regional Economy and Society

Chapter 1

Chapter 4   Economical and Political Proposal
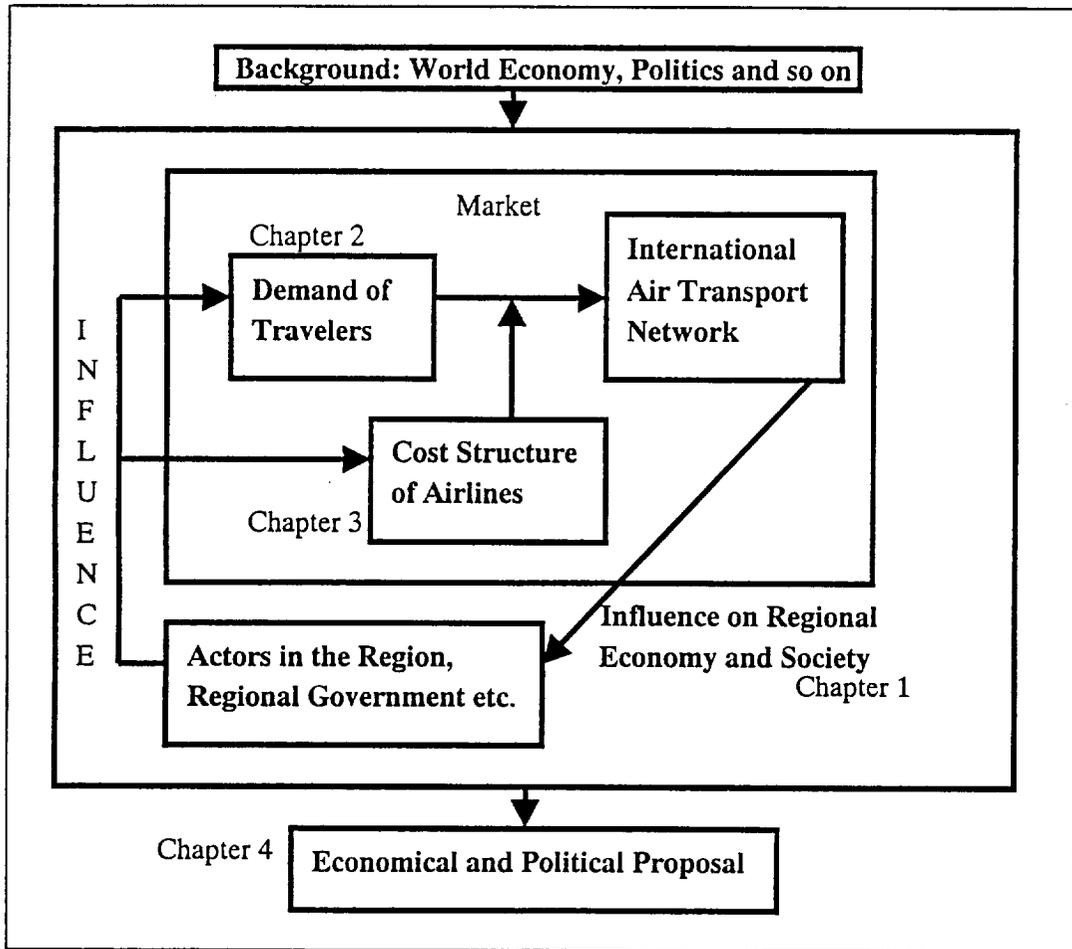
Figure 1   The structure of this paper

as a study area. Chapter 3 explains an analytical examination of airlines' cost structure, and the results of this chapter are used to examine the feasibility of results obtained in chapter 4. In the fifth chapter, as the conclusion of this paper, several proposals are summerized.


## 2 PREFERABLE ARRANGEMENT OF INTERNATIONAL AIRPORTS IN A REGION: BASED ON THE DEMAND OF TRAVELERS

In this chapter, the preferable arrangement of international airports in CS region in Japan The CS region is a part of western Japan, and has extended around Hiroshima City. Table 1 and Figure 2 show the basic features of this region.

Table 2 explains the terms used in this analysis. Five cases are considered as international airport arrangement. In the Case 1, that all international travelers from CS region gather to the Seoul new international airport once. In the Case 2, all travelers gather to three major airports, that is the Seoul new international airport, the Kansai International Airport or the Fukuoka airport. The Hiroshima airport, that is the busiest airport in the CS region, is added as an international airport in "Case 3". Izumo and Takamatsu airports, that are major airports in the Japan and Pacific Sea sides of the CS region are added in Case 4. In Case 5, all of the airports in the CS region, except aerodromes and bases are considered as the international airports for Southeast Asia.

The process of estimation is summarized in Figure 3. Our analysis is composed of eleven parts. These can be brought together as five stages. We assume five arrangement cases of international airports around CS region in the next century, from the fully concentrated case (Case 1) to the fully dispersed case (Case 5). In case of the concentrated case, it takes more time and more money to access to the few international airports, but the frequency from the international airport to each foreign destination is rather well. In case of the dispersed case, the opposite situation will be occurred. Based on the trade-off relationship like this, the Total Travel Cost (TTC : includes the frequency cost) for travelers in 2020 is calculated.   In the next chapter, the feasibility of each arrangement case is examined from airlines' viewpoint. In this paper, Southeast Asia is selected as a destination, and Singapore Changi airport is chosen as the "key airport " for the calculation of TTC.

Table 1   Basic data of CS region and Prefectures

| | Population | Area | GDP | Number of persons traveling abroad |
|---|---|---|---|---|
| Unit | thousand | km² | 100 million yen | person |
| Year | 1997 | 1995 | 1994 | 1996 |
| Okayama | 1953.5 (1.6) | 7111.1 (1.9) | 73417 (1.5) | 164808 (1.0) |
| Shimane | 770.7 (0.6) | 6706.7 (1.8) | 22881 (0.5) | 43618 (0.3) |
| Hiroshima | 2873.3 (2.3) | 8474.8 (2.2) | 106678 (2.2) | 274285 (1.6) |
| Tottori | 619.4 (0.5) | 3507.0 (0.9) | 20323 (0.4) | 49755 (0.3) |
| Yamaguchi | 1547.6 (1.2) | 6110.1 (1.6) | 55154 (1.1) | 111730 (0.7) |
| Ehime | 1521.6 (1.2) | 5675.2 (1.5) | 48504 (1.0) | 103137 (0.6) |
| Kagawa | 1034.0 (0.8) | 1875.2 (0.5) | 35891 (0.7) | 86968 (0.5) |
| Kochi | 824.4 (0.7) | 7104.1 (1.9) | 23623 (0.5) | 44161 (0.3) |
| Tokushima | 837.2 (0.7) | 4144.4 (1.1) | 24470 (0.5) | 62146 (0.4) |
| CS region | 11981.7 (9.6) | 50708.6 (13.4) | 410941 (8.5) | 940608 (5.6) |
| Japan | 125257 (100) | 377829 (100) | 4829473 (100) | 16694769 (100) |
| Source | Ministry of Home Affairs | Geographical Survey Institute | Economic Planning Agency | Ministry of Justice |

Notice: Figures in parenthesis are percentage of Japan.

100 million yen = approximately 9786.65 US$ (average of 1994).

Figure 2  The CS region

The number of travelers from/to each cities and counties in the CS region are estimated.

Travel costs for each access transportation are estimated.

Travel costs for air transport are estimated.

Stage 1    Analysis 1

Analysis 2        Analysis 3

Stage 2

The Minimum Hinterland of each airport in CS region is determined.

Analysis 4    →    Analysis 5

Travel cost for each city and county for each international airport arrangement case is estimated.

Stage 3    Analysis 6

The frequency cost is estimated.

Analysis 7    Analysis 5 + 7

The number of travelers from each international airport is estimated.

Stage 4

The total travel cost (TTC) per traveler to each city and county is estimated for each arrangement case of international airport.

Analysis 8

Sum up

Consolidate the results of analysis 8 into five categories.

Analysis 9

Analysis 10

Conclusion

Cost and Income structure of airlines are estimated, and the results are used to examine analysis 9.

Figure 3    The calculation flow

Table 2　Term used in this paper

| Term | Explanation |
|---|---|
| Airport | Civil Airports not include commuter aerodrome, such as Hiroshima West Aerodrome and Okanan Aerodrome. |
| Arrangement Case of International Airport | Case 1 : Seoul New International Airport<br>Case 2 : Seoul, Kansai International Airport and Fukuoka Airport<br>Case 3 : Airports in case 2 + Hiroshima Airport<br>Case 4 : Airports in case 4 + Izumo Airport and Takamatsu Airport<br>Case 5 : All airports in the Chugoku-Shikoku region |
| Cities and Counties | All cities and counties in Chugoku-Shikoku region as of 1996. |
| Frequency Cost | Frequency means the chance to travel to Southeast Asia.<br>Frequency Cost = $N / 2 \times TV \times 0.19$<br>Where : $N$ = Number of flights per day<br>$TV$ = Time value in 2020 (explained in Table 2 )<br>$0.19$ = Share of travelers who emphasize the importance of departure date and time |
| Minimum Hinterland | The cities and counties where the travel cost to one airport is cheaper than the other airports.<br><br>If　$M_{i1} + T_{i1} < M_{ij} + T_{ij}$,<br>Then　City "i" is included in the Minimum Hinterland of airport "1".<br>Where　$M_{ij}$ = Monetary cost from city "i" to airport "j".<br>$T_{ij}$ = Time cost from city "i" to airport "j".<br>$j = 1, 2, \cdots, n$ |
| Total Travel Cost | Travel Cost + Frequency Cost |
| Travel Cost | Monetary Cost (fares, charges and so on) + Time Cost (Travel time. The transfer time is included.) |
| Travelers | Travelers who travel from Chugoku-Shikoku region to abroad. Foreigners who come back to their country or go to another country from Chugoku-Shikoku region are included. |

## 2.1 Processing of the basic data (stage 1 : analyses 1 to 3)

This is a stage where basic data is processed. The number of travelers for Southeast Asia in all cities and counties is estimated in the CS region in 2020 (analysis 1). To estimate the number of foreign visitors to each city and county, we first averaged the results of annual reports, from 1986 to 1990, of International Travel Promotion Society. Then, based on the assumption that visitors' nationality ratio is the same all over Japan, the number of foreign visitors to each city and county is estimated. "Annual Statistics on Immigration Control" for 1995, "Population Census 1995" and results of the report by Mitsubishi Research Institute are also referred to estimate the number of travelers in 2020.

In analyses 2, the travel costs when car, railway, bus and marine transport are used are estimated with a regression method and so on. As travel cost contains a time value. The estimation method is also shown in table 4. The rental charge of parking lot is estimated as follows.

$$P = (UP / AN) \times (APD / 2) \qquad (1)$$

where    P :  Parking fee per one international passenger
           UP:  Unit parking fee per day,
           AN : Average passengers number per car (2.37 persons)
           APD: Average parking days of travelers (8.32 days)

AN is average number of passengers per car, which calculated based on a survey at the international arrival exit of the Hiroshima Airport, held on June 4th 1998. AN was estimated to be 2.37 persons. APD is the weighted-average of travel days for Japanese and foreign travelers to Japan from 1976 to 1995. It was estimated to be 8.32 days. UP is 1000 yen per day, except for the parking of Kansai International Airport, Matsuyama Airport and Takamatsu Airport. These three exceptions are charging unit fee more than 1000 yen per day in 1996.

As an international aviation fare, we assume that more local cities will inevitably receive the application of international direct or an add-on fare system, in analysis 3. Namely, by the year 2020, it will be expected that all airports in CS region will adopt the same fare system as the major airports in Japan.

## 2.2 Estimation of travel cost excepting frequency cost (stage 2: analyses 4-5)

The Minimum Hinterland of each airport in CS region is determined in analysis 4. In order to estimate the access cost from each city and county in and around CS region to airports, we assume that all travelers depart from city office or from the public office of the biggest town or village in each county (in Japanese "gun"). Figure 4 shows the results of Minimum

Table 3  Estimate Method and Estimated Value of Travel Cost and Time Cost

| | | Estimate Method and Estimated Value | | Note |
|---|---|---|---|---|
| Time Cost | | TV=W/H<br> where<br>TC :Time Cost<br>W: Wage per employee who work for<br>    more than five employee enterprises<br>H: Gloss real working hour per employee<br>    same as W<br><br>Estimated Value : 3408.28Yen/hour | | Almost the same method that used in estimation by Ministry of Construction of Japan |
| Travel Cost for Running on Road | Average Running Speed | High-standard Major Road     90km/h | | |
| | | Ordinary Toll Road          50km/h | | |
| | | Ordinary Road               40km/h | | |
| | Amount of Fuel Consumption | Estimation by Ministry of Construction in Japan | | |
| | Average Passengers per Car | 2.37 Passengers per Car | | Investigation of the actual situation at the Hiroshima Airport. |
| | Toll | High-standard Major Road<br>  Estimated with trend method<br>  Estimated Value: 1.3 times in 1996 | | Pooling system |
| | | Honshu-Shikoku bridges<br>  Same as present situations or<br>  same as the planned amount | | Pooling system. Too-high toll of Seto-chuo Road has already been set. |
| | | Ordinary Toll Road<br>  Already-opened : Free<br>  The Others    Equal to High<br>                     Standard Major Road | | Redemption assumed to be finished |
| | Fuel (gasoline) | Assumed to be 90 yen/l. | | There will be no extreme price fall since gasoline tax in Japan is very high. |
| | Parking | Kansai International Airport<br>                23,200Yen/4.16days<br>Matsuyama Airport<br>                6,242Yen/4.16days<br>Takamatsu Airport<br>                4,994Yen/4.16days<br>The Others    4,162Yen/4.16days | | "4.16 days " is the weighted-average of travel days from 1976 to 1995 |
| Cost for Using Public Transport except aviation | The Time Required | Railway    85% of present situation | | Speed up is assumed. |
| | | The Others Same as present situation | | |
| | Fare | Increase along wage increase rate<br><br>Estimated Value : 1.34 times 1996 | | Wage increase rate is considered in Japan |
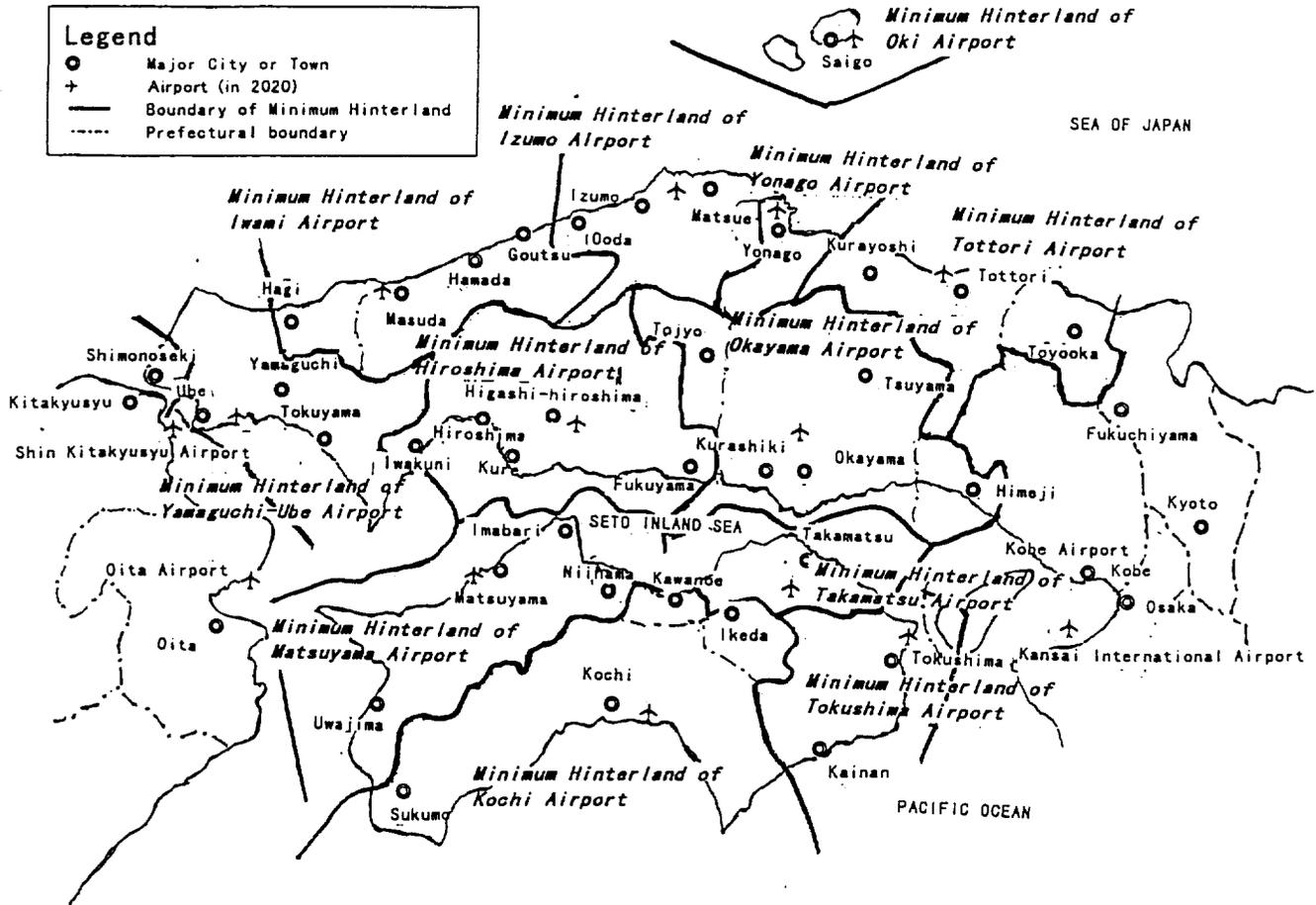
Figure 4   Minimum Hinterland of Each Airport

Hinterland for each airport. In analysis 5, the travel cost for each city and county is estimated for each case of international airport arrangement. The travel cost except for the frequency cost can be estimated in this stage.

## 2.3 Estimation of frequency cost (stage 3 : analyses 6 and 7)

In this stage, the frequency cost for each destination is estimated for each arrangement case of international airport.

In analysis 6, the number of travelers from each international airport is estimated for each arrangement case of international airport. This estimation is based on the assumption that traveler will select international airports in a divide manner as follows:

$$Y = -X + 2 \tag{2}$$

Where:

$Y$ = divide magnificent of travelers from/to each city or county, of airport k

$X = K / S \ (0 < X \leqq 2)$

$K$ = monetary cost for access to airport k + time cost for access to airport k

$S$ = monetary cost for access to airport s + time cost for access to airport s

airport s = the airport of whose monetary cost for access + time cost for access
is smallest for travelers from/to each city or county

In analysis 7, the Frequency Cost is estimated (See Equation 2~4). First, the number of travelers is divided by the break-even passenger number of typical large airplanes to get the possible number of flights per day. Break-even passenger number is assumed as 240 (400 × 0.6). In addition, we assume the ordinary departure time is from 6 o'clock A.M. to 22 o'clock P.M. (16 hours).

$$PN = (TN / BE) \times (1 / 365) \tag{3}$$

where       PN : Possibile number of flight per day
            TN : Travelers number in 2020
            BE : Break-even passenger number (240 for a large airplane)

$$AWT = (16 / PN) \times (1 / 2) \tag{4}$$

where       AWT : Average Wait Time

$$FQC = AWT \times TVC \times k \qquad\qquad (5)$$

where          FQC : Frequency Cost

TVC: Time Value Cost in 2020 (3408.28 yen per hour)

k: Percentage of travelers who will be sensitive to the day and time of departure. It is estimated that $k = 0.19$, based on the questionnaire held at the Hiroshima airport international waiting lobby.(March 16, 1998 ～ March 23, 1998, N=495)

## 2.4 Estimation of total travel cost (stage 4 : analyses 8 and 9)

Analyses 8 and 9 are stages in which the results are obtained. In analysis 8, the result of analysis 5 and analysis 7 is summed up. Consequently, we estimate the total travel cost per traveler to each city and county is estimated for each case of arrangement of international airport.

In analysis 9, we consolidate the results of analysis 8 into five categories. That is to say, we consolidate to 1: "Whole area of CS region"  2: "The Japan Sea side of Chugoku region" 3: "The Seto Inland Sea side of Chugoku region"  4: "Shikoku region" and 5: "Minimum hinterland of each airport in CS region"..

## 2.5 Simulation Results

Graphs for Southeast Asia are shown as Figure 5-1 to Figure 6-4. In each graph, the scale of the vertical axis is Total Travel Cost in 2020 (one way, Yen : 1Yen = approximately 0.0142US$, 0.038272Belgium Franc in June 30th, 1998), and the scale of horizontal axis is Arrangement Case of International Airport (Case 1～5). These results are considered noting the following two principles. First, the smaller the total travel cost is, the more desirable for the travelers. This is called "Low-cost principle". If two or more International Airport Arrangement Cases have almost similar Total Travel Cost, we regard the case with more numbers of international airports as the preferable case. This is based on the idea that international airport is becoming one of the "Regional Minimum" infrastructure, We call this "Regional Minimum principle". Please note that the lowest-cost case is NOT the only preferable (optimal) case, but one of the preferable cases. We should not declare only from the travelers' viewpoint. So if we cannot judge a case is preferable or not from the travelers' viewpoint, then examinations from other view points are required

From figure 5-1 to 5-4, TTCs calculated on the condition that all aircraft are large (Boeing 747 class, 400 seats). From Figure 6-1 to 6-4, as explained in Table 2, TTCs calculated on the condition that medium size aircraft (Boeing 767 class, 250 seats) or small size aircraft

(Boeing 737 class, 150 seats) are used for several routes. Each sub-region (for example, the Seto Inland-sea side of Chugoku region) is defined as the sum of several MHs.

First, Figure 5-1 and Figure 6-1 show Total Travel Cost from each sub-region. Seto Inland sea side of Chugoku region is shortened as C-Seto region im Figures, and Seto Inland sea side of Shikoku region is shortened as S-Seto region in Figures. For travelers from the Minimum Hinterland in the Japan-sea side of Chugoku region and the Pacific side of Shikoku region, Case 5 is 4000∼6000 Yen higher than Case 4. Therefore, it can be said that to make direct regular routes to Southeast Asia from each local airports in these two sub-regions will have comparatively few meaning for travelers from/to these two sub-regions. For travelers from the other two sub-regions, it is not easy to declare that Case 5 will not be preferable.

Figure 5-2 and Figure 6-2 show Total Travel Cost from Minimum Hinterlands in the Japan-sea side of Chugoku region. In figure 5-2, we can see that Cases 2, 3 or 4 can be the preferable case for the travelers from/to each Minimum Hinterlands. In Cases 4 and 5 shown in Figure 6-2, it is clear that TTC can be fairly reduced if airline will change aircraft from large type to middle or small type. Each Minimum Hinterland in this sub-region has comparatively small demand volume, so Case 5 will not be preferable if airline uses large aircraft. Now, we have to examine the influence of changing aircraft from airlines' viewpoint, in the next chapter.

Figure 5-3 and Figure 6-3 show Total Travel Cost from/to each Minimum Hinterland in the Seto Inland-sea side of Chugoku region. In Figure 5-3, we can see that Cases 3, 4 or 5 will be preferable for the travelers from/to the Minimum Hinterland of Hiroshima Airport, Cases 2 or 5 for the Minimum Hinterland of Okayama Airport. For the travelers from/to the Minimum Hinterland of Yamaguchi-Ube Airport, Case 2, 3, or 4 could be preferable. These three Minimum Hinterlands have comparatively large demand volume in the CS region. Especially, it is estimated that Hiroshima Airport have the largest demand volume, so if the arrangement case is changed from Case 3 to Case 4 or Case 5, the TTC from/to it will not be raised well. Okayama Airport is estimated to have second largest demand volume, so if the arrangement case is changed from Case 4 to Case 5, the TTC from/to it will not be raised, but be clearly reduced. Yamaguchi-Ube Airport is estimated to have third largest demand volume in 2020, but TTC in Case 5 may be too high. In Figure 6-3, it is shown that TTC from/to MH of Yamaguchi-Ube are reduced if aircraft size is changed. So, we have to examine the influence of changing airplanes from/to Yamaguchi-Ube Airport in Case 5 in the next chapter.

Figure 5-4 and Figure 6-4 show Total Travel Cost from each Minimum Hinterland in the Sikoku region. In Figure 5-4, we can say that Cases 2 and 3 can be preferable for travelers from/to each Minimum Hinterland, and Case 4. can be also preferable. Now, from Figure 6-4, in Cases 4 and 5, it is clear that TTC can be significantly reduced if airline change
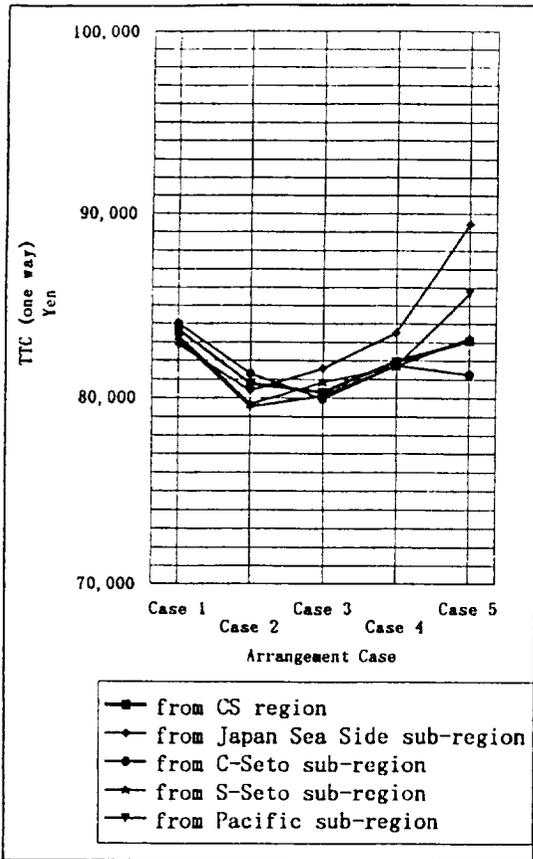
Figure 5-1 TTC for each sub-region

Legend:
- from CS region
- from Japan Sea Side sub-region
- from C-Seto sub-region
- from S-Seto sub-region
- from Pacific sub-region
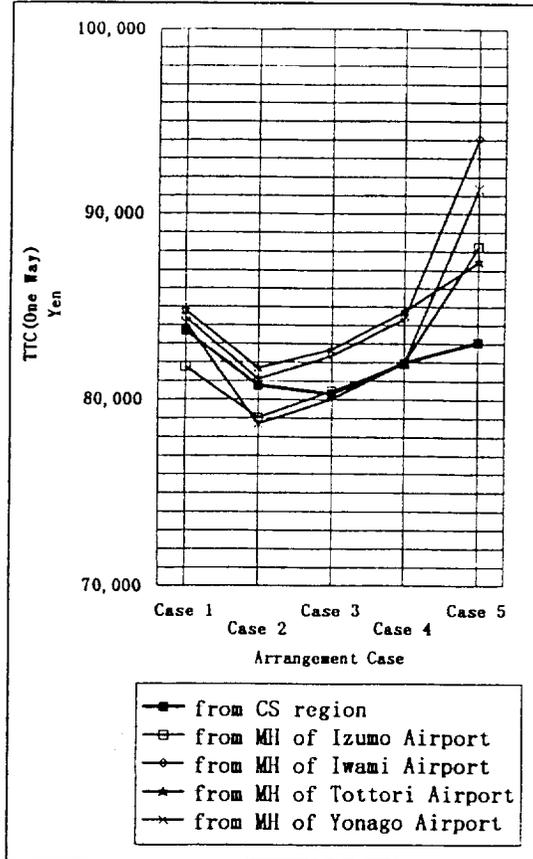


Figure 5-2 TTC for each MH in the Japan Sea
Side of the Chugoku region

Legend:
- from CS region
- from MH of Izumo Airport
- from MH of Iwami Airport
- from MH of Tottori Airport
- from MH of Yonago Airport
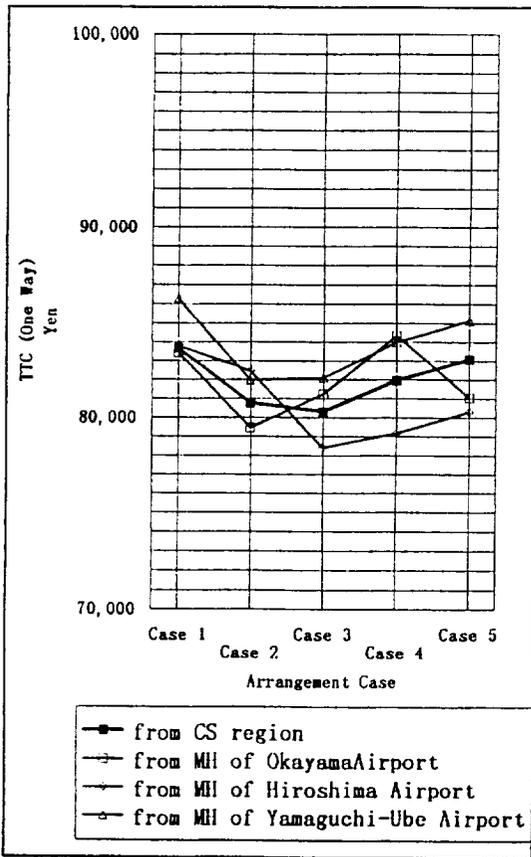


Figure 5-3 TTC for each MH in the Seto Inland-sea
Side of the Chugoku region

Legend:
- from CS region
- from MH of OkayamaAirport
- from MH of Hiroshima Airport
- from MH of Yamaguchi-Ube Airport
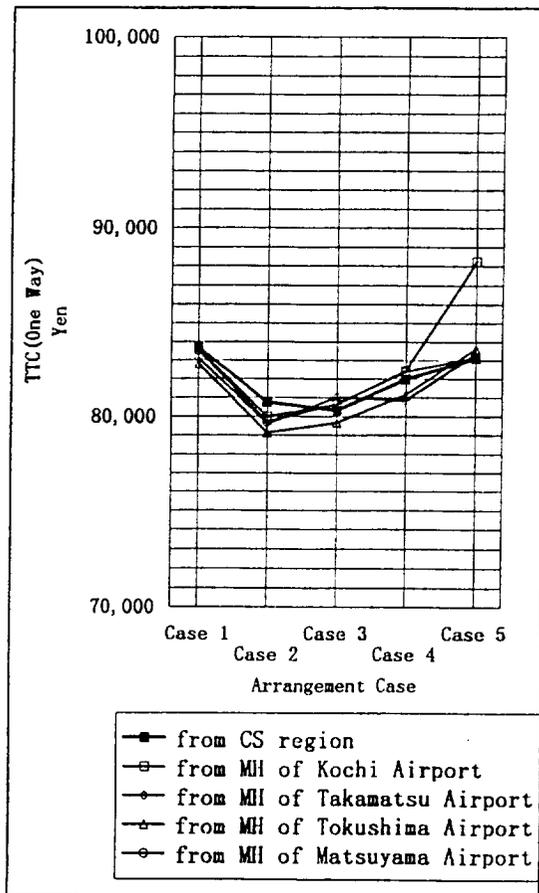


Figure 5-4 TTC for each MH in the Sikoku region

Legend:
- from CS region
- from MH of Kochi Airport
- from MH of Takamatsu Airport
- from MH of Tokushima Airport
- from MH of Matsuyama Airport
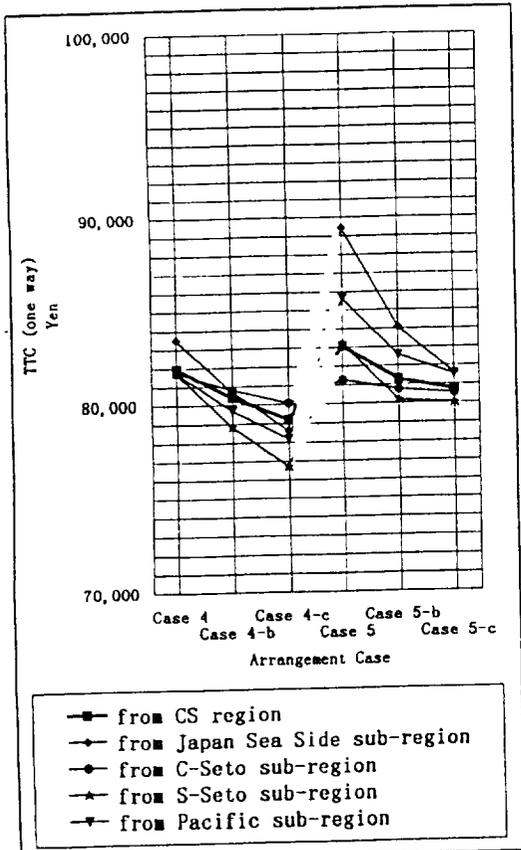
Figure 6-1 TTC for each sub-region
    Aircraft are changed in several routes

Legend for Figure 6-1:
- —■— from CS region
- —◆— from Japan Sea Side sub-region
- —●— from C-Seto sub-region
- —▲— from S-Seto sub-region
- —▼— from Pacific sub-region
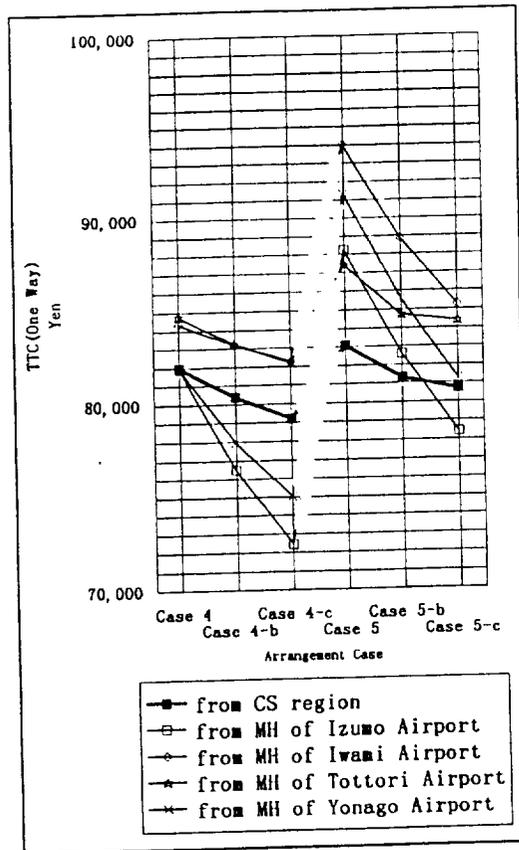


Figure 6-2 TTC for each MH in the Japan Sea
    Side of the Chugoku region
    Aircraft are changed in several routes

Legend for Figure 6-2:
- —■— from CS region
- —□— from MH of Izumo Airport
- —◇— from MH of Iwami Airport
- —▲— from MH of Tottori Airport
- —✕— from MH of Yonago Airport
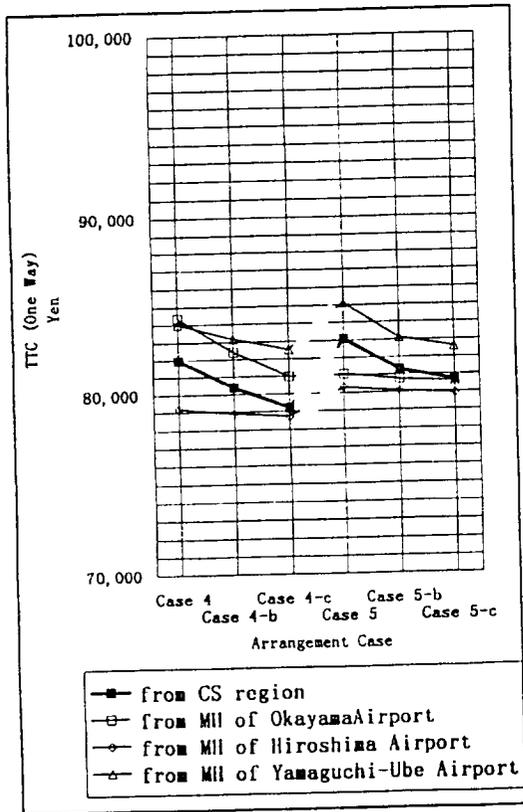


Figure 6-3 TTC for each MH in the Seto Inland-sea
    Side of the Chugoku region
    Aircraft are changed in several routes

Legend for Figure 6-3:
- —■— from CS region
- —□— from MH of OkayamaAirport
- —◇— from MH of Hiroshima Airport
- —△— from MH of Yamaguchi-Ube Airport
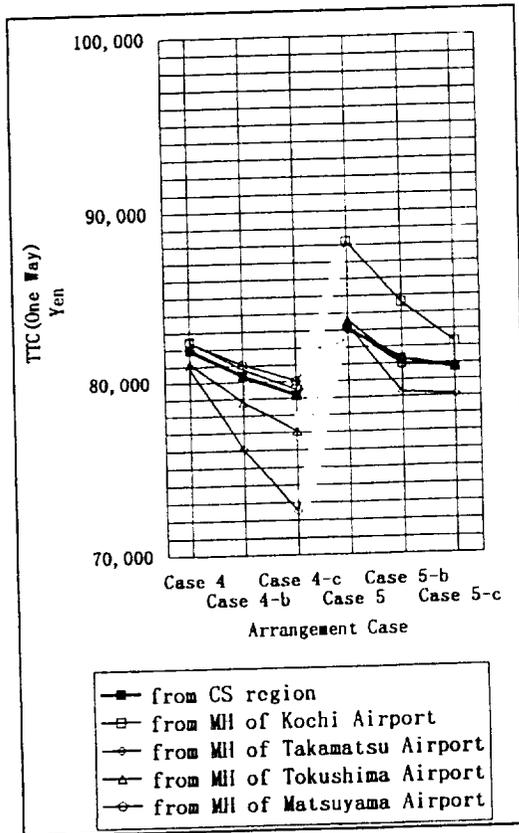


Figure 6-4 TTC for each MH in the Sikoku region
    Aircraft are changed in several routes

Legend for Figure 6-4:
- —■— from CS region
- —□— from MH of Kochi Airport
- —◇— from MH of Takamatsu Airport
- —△— from MH of Tokushima Airport
- —◇— from MH of Matsuyama Airport

aircraft from a large type to middle or small types. We have to examine the influence of changing aircraft from airlines' viewpoint, in the next chapter.

# 3 COST STRUCTURE OF AIRLINES AND ARRANGEMENT REGIONAL AIRPORTS

In this chapter, the cost structure of airlines is analyzed. The main objective of this analytical stage is to examine the results in Chapter 2 by airlines' viewpoint. In a word, to calculate the influence of each arrangement case of international airport and of changing airplane on the cost and income structure of an airline is the main objective.

There are two approaches to examine airlines' cost and income structure. One is from a macro (cost and income structure of the air transportation industry or airlines) viewpoint, and the other is from a micro (cost and income structure of each route) viewpoint. From a macro viewpoint, we can focus on the structural difference between each airline and discuss about regional policy. From a micro viewpoint, the structural difference between each route can be focused on to discuss about regional policy. So, both of these would be important to discuss about feasibility of arrangement cases of international airport. However, in this paper, discussion is done mainly from the macro view point. Analysis and discussion from the micro viewpoint will be done in our further work.

When an airline will begin to operate international regular flights from/to several airports in CS region, or changes aircraft from/to several airports in the CS region, (1) the total ton-kilometer performed (OUTPUT)  (2) the average stage length (ASL)  (3) the average scale (payload) of aircraft (APL) (4) aircraft departures per day (FRQ)  (5) average load factor (LF) will be changed. So, at the beginning, we estimate the cost and income structure of airlines' in Asia, by using OUTPUT, ASL, APL, FRQ, LF and other explanatory variables. Then, we calculate the changing rate of these four variables for each arrangement case of international airport in the CS region. After that, the influence of each arrangement case of international airport and of changing airplane on the cost and income structure of an airline will be calculated.

## 3.1 Estimation of Cost and Income Structure of Airlines' in Asia

In order to analyze on the cost structure or productivity of airlines, there are several approaches. The easiest way is to analyze partially about, for example, "passengers per employee" or "revenue ton-kilometer per employee". The limitations and uses of partial productivity measures like these were discussed in Windle and Dresner (1992). Caves, Christensen and Tretheway (1981) (1984) used Translog function to estimate generalized total or variable cost structure function. Christensen, Jorgensen, and Lau (1973) pioneered

this functional form, and this form has a good point that it enables us to measure the return to scope through Second-order term. However, this has a week point that it needs much sufficient sample number. Gillen, Oum and Tretheway(1990) and Mcshan and Windle (1990) also used Translog functional form. In Japan, there are several former analyses about cost structure of Japanese airlines. Takahashi (1985) used Cob-Douglas function and analyzed about the cost structure and return to scale (RTS) for Japanese airlines. In order to promote detailed analysis, he examined five Network Variables, six Technology Variables at the beginning, and after that made multi regression models with one Scale Variable. Masui and Yamauti (1990) also used Cob-Douglas function and analyzed about the cost structure of Japanese three major airlines, but this regression analysis was an extra one. Their inclusive research about aviation was one of the best one. Kinugasa (1993) (1994) (1995) mainly used Translog function and analyzed the cost structure, return to density (RTD) and RTS of Japan Airlines (JAL), All Nippon Airways (ANA), and Japan Air System (JAS). Murakami (1994) (1995) (1996) used Cob-Douglas function and analyzed the cost structure, RTD, RTS, and domestic aviation fare system of Japanese airlines include two local airlines

In this paper, we use Cob-Douglas functional form to estimate the cost structure. The general model is as follows:

First, it is assumed that

$$Y = F(X_1, X_2, \cdots, X_n) \tag{6}$$

where Y : Output

$X_i$ : Input amount of production factor i (i = 1 $\sim$ n)

Now, the optimal combination of production factors are shown as $(X_1{}^*, X_2{}^*, \cdots, X_n{}^*)$. Then, Y can be written :

$$Y = F(t X_1{}^*, t X_2{}^*, \cdots, t X_n{}^*) = t^k \tag{7}$$

where t : Magnification (Because we assume Cob-Douglas function, which is defined as a homogeneous function)

k : Sum of coefficient , that is to say,

$$k = \sum_{i}^{n} \frac{\partial \ln F}{\partial \ln X_i} \tag{8}$$

k means the elasticity of production for scale.

Next, if airlines keep the cost-minimum rule, then the cost function can be written:

$$TC = TC (W_1, W_2, \cdots , W_n, Y)$$
$$= (W_1X_1{}^* + W_2X_2{}^* + \cdots W_nX_n{}^*)t = lt \quad (l>0) \tag{9}$$

where    TC : Total cost

       $W_i$ : Price of production factor i (i = 1 $\sim$ n)

       $l = W_1X_1{}^* + W_2X_2{}^* + \cdots W_nX_n{}^*$ : constant

Now, from the equations (7) and (8), it can be written:

$$TC = lY^{1/k} \tag{10}$$

Then, total cost function is :

$$lnTC = a + (1 / k)lnY \tag{11}$$
where

         a : constant

The TC can be estimated by production variables, for the output Y.

Now, our model can be written:

$$lnTC = lnTC \text{ (OUTPUT, ASL, APL, FRQ, LF, LP, FP, CP, EXC)} \tag{12}$$
where

| | |
|---|---|
| TC : Total Cost , | |
| OUTPUT : Total Revenue Tonne-Kilometers | |
| ASL : Average Stage Length, | Y in equation (9) |
| APL : Average Payload, | |
| FRQ: Aircraft Departures per Day, | |
| LF : Average Load Factor, | |

| | |
|---|---|
| LP : Unit Labor Cost, | |
| FP : Unit Fuel Cost, | W in equation (9) |
| CP : Unit Capital Cost, | |
| EXC : Dollar Exchange Rate | |

OUTPUT is defined as follows, since there are some airlines that have original definitions of passenger weight. For Example, Japanese airlines use 102.5kg for first class of international routes, 92.5kg for economy class of international routes, and 75.0kg for domestic routes, instead of world standard, that is, 90.0kg.

$$\text{OUTPUT} = \text{ASPK} \times 0.09 + \text{RSTK} + \text{RCTK} \tag{13}$$

where 　　　ASPK : Available Scheduled Passenger Kilometers
　　　　　　RSTK : Revenue Scheduled Tonne-Kilometers of Freights
　　　　　　RCTK : Revenue Chartered Tonne-Kilometers

APL is a substitute variable for average size of aircraft. We also examined Average Maximum Take-off Weights (AMTW) as a substitute variable, but AMTW's correlation with TC was lower than APL. Therefore, we choose APL. APL and AMTW are calculated as follows:

$$\text{APL} = \text{ATK} / \text{KF} \tag{14}$$

where 　　　ATK : Available Tonne-Kilometers
　　　　　　KF : Kilometers Flown

$$\text{AMTW} = \sum_{i=1}^{n} (NA_i \times MTW_i) / \sum_{i=1}^{n} NA_i \tag{15}$$

where 　　　$NA_i$ : Number of Aircraft type i (i = 1~n)
　　　　　　$MTW_i$ : Maximum Take-off Weights of Aircraft type i (i = 1~n)

In this paper, TC is deflated by GDP deflator and realized to 1995 price. Private final consumption expenditure deflator deflates LP. Total wholesale price index deflator deflates FP. CP is deflated by private total fixed capital formation deflator.

For estimation of total income(TI), we use the same kind of model as TC:

$$\ln \text{TI} = \ln \text{TI} (\text{OUTPUT, ASL, APL, FRQ, LF, LP, FP, CP, EXC}) \tag{16}$$

## 3.2 Data

The airlines analyzed in this paper are: Korean Airlines (KAL), Cathay Pacific (CPA), Thai Airways (THA), Garuda Indonesia (GAI), Singapore Airlines (SIA), and Malaysian Airline System (MAS). Since we choose Southeast Asia for the case study, we have to attach importance to airlines in Asia.

We collected data mainly from ICAO "Fleet and Personnel", ICAO "Financial Data", ICAO"Traffic" and IATA "World Air Transport Statistics", and, if necessary, from the annual reports, handouts and home pages on internet. Observations used are from 1981 to 1995, but following years are deleted because of lacking of some data: KAL (82,89), MAS (81~87, 92,93), THA (85, 95), GAI (81,82,86,87,89,92,94,95), CPA (81~88), SIA (81,95).

## 3.3 Calibrating Results

Using the model and data explained above, we estimate airlines' total cost function. All explanatory variables and dependent variable are in natural logarithms, therefore partial regression coefficients are all interpretable as cost elasticities that evaluated at the sample mean. As a limitation of this paper, the elasticities of LP, FP and CP are not equivalent to shares in total cost (that is, sum of coefficient of these is not limited to be 1). At the beginning, we used all variables to estimate correlation matrix. Then, after we checked the significance of each variables and also examined the existence of multi colinearity, some variables are deleted. As a consequence, ASL and APL were excluded in both models of TC and TI.

The results of regressions are shown in Table 4. Revised R square and F value of each regression equation are all significantly high, although Durbin-Watson statistics of each regression equation are not so good.

## 3.4  Arrangement case of international airports and airlines

The influence of changing arrangement case of international airports on airlines' cost and income structure will be examined here. First, the changing rates of OUTPUT, ASL, APL, FRQ and LF for each arrangement case of international airport are calculated.

The imaginary airline, whose data set are calculated by averaging KAL, MAS, SIA, THA, GAI and CPA's data, is assumed as only airline serves between CS region and Southeast Asia. For this calculation, data for 1996 are used. However, because TC and TI of GAI are not available, TC and TI are calculated by averaging other five airlines' data. Here, as shown in Table 5, Case 4 and 5 are divided into three. Secondly, the influence of each arrangement case of international airport and of changing airplane on the cost and income structure of an airline are calculated. Table 6 shows the magnification to the data of the assumed airline in 1996. Thirdly, the improve amount of cost and income are calculated. At that time, explanatory variables besides OUTPUT, FRQ and LF are assumed to be fixed.

The results of calculation are shown in Table 7. If the imaginary airline starts regular flights from Southeast Asia to Hiroshima (Case 3), the benefit of the airline will be 93.573 million yen per year. If the airline extends the regular flights to Izumo and Takamatsu with large aircraft (Case 4), it's benefit will be 93.573 million yen + 1.853 million yen = 95.436 million yen. If the airline changes aircraft from large one to medium one (Case 4-b), it's

Table 4　Calibrating results of TC and TI

| Variables | TC | TI |
|---|---|---|
| Constant | -5.428 (-2.834) | -5.102 (-2.609) |
| OUTPUT | 1.147 (17.224) | 1.131 (16.637) |
| FRQ | 0.281 (5.859) | 0.244 (4.976) |
| LF | -1.217 (-2.908) | -1.251 (-2.929) |
| EXC | 0.064 (4.309) | 0.070 (4.574) |
| LP | 0.109 (2.264) | 0.116 (2.355) |
| FP | 0.239 (2.222) | 0.105 (0.951) |
| CP | 0.256 (3.270) | 0.241 (3.019) |
| R square (revised) | 0.940 | 0.938 |
| F value | 94.549 | 91.117 |
| DW | 0.824 | 0.751 |
| Degree of Freedom | 57 | 57 |

**t value in parenthesis**

Table 5 Airplane for each airport : from/to Southeast Asia, in each Case

| | Used airplane for each airport : from/to Southeast Asia | | |
|---|---|---|---|
| | Large size airplane | Medium size airplane | Small size airplane |
| Case 4 | Hiroshima, Izumo, Takamatsu | (non) | (non) |
| Case 4-b | Hiroshima | Izumo,　Takamatsu | (non) |
| Case 4-c | Hiroshima | (non) | Izumo, Takamatsu |
| Case 5 | All airports in the CS Region | (non) | (non) |
| Case 5-b | Hiroshima, Okayama | Izumo,Iwami,Takamatsu, Kochi,　　Tokushima, Tottori, Matsuyama, Yamaguchi-Ube, Yonago | (non) |
| Case 5-c | Hiroshima, Okayama | Takamatsu, Tokushima, Matsuyama, Yamaguchi-Ube | Izumo,　Iwami, Kochi,　Tottori, Yonago |

Table 6 Changing rate of variables in each arrangement case

| Case No. | Magnification | | |
|---|---|---|---|
| | OUTPUT | FRQ | LF |
| Case 3 | 1.0020 | 1.0186 | 0.9189 |
| Case 4 | 1.0029 | 1.0331 | 0.8900 |
| Case 4-b | 1.0025 | 1.0397 | 0.8993 |
| Case 4-c | 1.0023 | 1.0508 | 0.9057 |
| Case 5 | 1.0050 | 1.0574 | 0.8234 |
| Case 5-b | 1.0042 | 1.0718 | 0.8410 |
| Case 5-c | 1.0041 | 1.0780 | 0.8441 |

Table 7 Arrangement case of airports and airline's cost and income

| Case No. | Compared with | Increase of TC (10 thousand Yen) | Increase of TI (10 thousand Yen) | Balance of increased TC and TI (10 thousand Yen) |
|---|---|---|---|---|
| | | ① | ② | ②－① |
| Case 3 | No * | 570,509.7 | 579,867.1 | 9,357.3 |
| Case 4 | Case 3 | 5,622.9 | 5,808.1 | 185.3 |
| Case 4-b | | 4,092.3 | 4,180.1 | 87.8 |
| Case 4-c | | 3,242.3 | 3,243.1 | 0.8 |
| Case 5 | | 19,198.1 | 19,884.1 | 686.0 |
| Case 5-b | | 16,054.4 | 16,534.8 | 480.4 |
| Case 5-c | | 15,597.9 | 16,030.9 | 433.0 |

*Note : In Case 3, an airline is assumed to start operate flights to Japan and handle all of the demands from/to CS region to/from Southeast Asia.

Table 8 Increase rate of TC and TI : compared with non flight case

| Case No. | Increase rate of TC (%) | Increase rate of TI (%) |
|---|---|---|
| Case 3 | 1.266 | 1.161 |
| Case 4 | 1.279 | 1.173 |
| Case 4-b | 1.275 | 1.170 |
| Case 4-c | 1.273 | 1.168 |
| Case 5 | 1.309 | 1.201 |
| Case 5-b | 1.302 | 1.194 |
| Case 5-c | 1.301 | 1.193 |

benefit will be 93.573 million yen + 0.878 million yen = 94.451 million yen. In Case 4-c, benefit will be 93.581 million-yen. If the airline extends the network to all airports in the CS region with large aircraft (Case 5), then it's benefit will be 93.571 million yen + 6.86 million yen = 100.433 million yen. In Case 5-b, benefit will be 98.377 million-yen. In Case 5-c, benefit will be 97.903 million-yen. It is clear that the extension network to the CS region is beneficial to the imaginary airline. It is also clear that benefit in larger aircraft Case is larger than smaller aircraft Case.

However, as shown in Table 8, increase rate of TC are estimated to be larger than that of TI. Namely, the airline can get benefit from the expansion of network to the CS region because the airline have sufficient energy. So, on the other hand, if the imaginary airline is in deficit, or there is no sufficient surplus, the airline will not manage to extend the network to the CS region. In this paper, the imaginary airline's data were produced from 6 airlines in growing Asia. The demand for international aviation in Asia is expected to continue growing, to be half of the world demand by 2010. So, it can be concluded that Case 4-b, 4-c, 5-b, and 5-c are feasible from the beneficial airlines' viewpoint. Regional government that has a plan to open international regular routes to Southeast Asia will be recommended to negotiate with airlines whose benefit is sufficient. However, they have to postpone the timing of starting routes, or decrease frequency or cease the routes if the expected airline's condition will turn to be worse.

## 4 CONCLUDING REMARKS

In this paper, the preferable arrangement of international airport is examined, based on the real data set. First, analysis based on travelers' viewpoint has been carried out. Next, the cost and income structure of Asian airlines were analyzed, in order to examine the results of travelers viewpoints' analysis. As a conclusion, from travelers' and airlines' viewpoint, it could be concluded that several comparatively small demand airports in the CS region like Izumo, Takamatsu, Iwami, Kochi, Tokushima, Tottori, Matsuyama, Yamaguchi-Ube and Yonago would also have chance to have international regular flights to Southeast Asia by 2020, on the condition that the medium or small size airplanes are used. Moreover, it could be realized for the sufficient-tough airline to extend network to CS region, but the other airline will not manage to do so. Hiroshima Airport and Okayama Airport will clearly be used as the international airport for Southeast Asia by 2020 because their hinterland is large enough .

There are several limitations in this paper. The first one is a lack of micro viewpoint. In the further work, the results of this paper have to be examined by the micro (characteristic of each route) viewpoint, to propose more concrete regional policy. The second is a lack of discussion about the timing and ordering of each airport's internationalization. The third is that this paper covers only Southeast Asia as the destination. The fourth limitation is that in

this paper cost and income structure is estimated limiting of within Asian airlines. In order to discuss regional policy, Japanese, European and USA airlines' structure also have to be estimated and compared to each other. The fifth is related with the estimation method of cost and income structure. In order to discuss about regional policy, "number of city served" variable had to be added. The last problem is also related with the method to analyze airlines' cost and income structure. The framework of this paper dose not adapt to the real airlines' several important behavior, such as co-operation, combination, and so on. These are all our reserch subjects in our further work.

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# A Simulation Technique for Analysis of Brazilian Airport Passenger Terminal Buildings

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# 1 INTRODUCTION

The Air Transport industry continues to show signs of improving health. From 31,000 thousands passengers carried in the world civil air transport in 1950 to 1,258 million passengers in 1995. International Air Transport Association (IATA) expects total international scheduled passengers traffic to grow at 6.6% for the five-year period ending in 1998. Boeing's forecast for the cargo industry predicts a 6.6% annual growth rate. Airbus predicts an annual growth rate of 5.1% in worldwide revenue passenger kilometers. The trends are to keep the growth rates positively.

In Brazil, to the next four-year period, investments are estimated in more than US$ 2,500 million in the air transport industry. The movement in the busiest Brazilian airport, the International Sao Paulo/Guarulhos, went beyond 12 million passengers in 1997.

Airport systems are normally near its saturation point: Belem, Fortaleza, Natal, Porto Alegre and Rio Branco Airport Terminal Buildings are under construction. The costs to extend or to refurbish some installation are too high! There are financial restrictions and environmental oppositions to enlarge those infrastructures. There are, more and more, a single choice to increase productivity: make more with less.

The usual procedures for designing and operating airport passenger terminal buildings normally create to either high operating and maintenance costs or passenger conflicts. Many researches have been conducted intending a reduction of "door-to-door" travel time, which contains an increasing proportion of ground time as compared with actual flight time.

As the aviation industry evolved, it became increasingly competitive and far more volatile. For the airport planner, this has meant designing terminals that could reach obsolescence before leaving the drawing board. In order to be able to compare a number of design alternatives and examine the "what if?" scenarios that are vital in today's environment the utilization of simulation models is suggested.

This paper develops a simulation technique that helps the designer "to see in operation" his solutions for existing problems or to analyze layout options as a function of previewed scenarios, thus futures conflicts can be predicted and avoided.


# 2 SIMULATION TECHNIQUE PROPOSED

The simulation technique developed is based on ARENA™ simulation system and can be executed in on a PC486 or higher computer over Win95 or OS/2 with 8 MB RAM. It was developed by Almeida (1997). Simulation packages like ARENA provide for the modeler flexibility and modeling power, this have been then one of the most used tool in quick operational analysis of proposed alternatives. Less software training than a C or FORTRAN simulator, is another ARENA highlight.

There are many factors (technical, market and support) that induce for this decision. Some users of this package in the Air Transportation industry are: American Airlines, British Airways, Quantas Airlines, US Air, Nothwest Airlines, SABRE Decision Technologies and many universities.

2

The methodology is simple and it allows the analysis of the acting of each component. Basically they cover 6 phases:
    (1) description of the problem
    (2) flow of information
    (3) data collection and treatment
    (4) construction of the model
    (5) verification and validation
    (6) analysis of the results

The description of the problem should be accomplished in the possible most detailed way. Operational politics, specific processes, employees' shift and other particularities of the system should be taken into account. The modeler should have enough information for the elaboration of the work flow in the components that is being analyzed.

In the second phase they are traced the flow of entities graphically (passengers and baggage), the regime of operations of the resources (employees' shift and other procedures), the processing time, the arrival distribution of passengers and other relative numeric characteristics to the problem.

The collection of the data is made through researches with the users (airlines, passengers, employees etc.) as presented by Goldner (1991). Basically a research project is developed where some data must be lifted up, they are organized in subjects that should receive a treatment and others are obtained empirically or by observation. The collected gross data are consolidated statistically and contained in way to supply the needs of the previous paragraph. Such data can be divided in: of entrance of the model (processing times, arrival distribution etc.) and of validation (number of people in the line, people in the wait room etc.).

The fourth stage understands the assembly of the logical part with the numeric part.

The fifth stage is a logical test, an application with extreme values, to get a consistent result. For example, for larger flows of passengers you must obtain longer lines or larger waits if the other conditions are kept constant. To get the validation of the model, one variable should be chosen as reference parameter. In the collection of data this variable should be quantified so that, after having executed the model, it can be compared with to exits of the same. In this point it is important the experience of the modeler for check if the obtained results are consistent to the observed in the practice.

Finally in the analysis of the results, the modeler should compile the data generated by the model and, starting from them, to produce the medium values and the possible distributions that will serve, then, to analyze the problem of two manners: the quantitative and the qualitative way.


## 3 A CASE STUDY

Sao Jose of Campos is a city of medium load, about 500.000 inhabitants, located between Rio de Janeiro and Sao Paulo. A technical-scientific center where industries associated to

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the technology prevail. It is denominated of the Capital of the Airplane, besides to aerospace section, it shelters chemical, automobile industries and others linked to the telecommunications. The airport movement has been growing significantly in the last two years, after the implementation of the Plano Real for the central government. Parallelly the airline TAM has opened flights to São Paulo, in spite of the proximity, and other destinies, besides the traditional available flights for Rio de Janeiro for the airline Rio-Sul. The recently inaugurated airline Passaredo chose Sao Jose dos Campos as one of its base.

The passenger movement in about 85% is due business reasons and 10% to the tourism. In the month of October of 1997 research was accomplished where were characterized as the passengers' main destinations:

**Table 1 - Main Destinations From Sao Jose**

| City-destinations | Percentages |
|---|---|
| Sao Paulo | 32 |
| Rio de Janeiro | 29 |
| Porto Seguro | 26 |
| Belo Horizonte | 14 |
| Curitiba | 7 |
| Vitoria | 4 |
| Salvador | 4 |
| Ribeirao Preto | 3 |

In terms of airline market share, based on that same month, it was obtained:

**Figure 1 - Sao Jose Airport: Market Share**
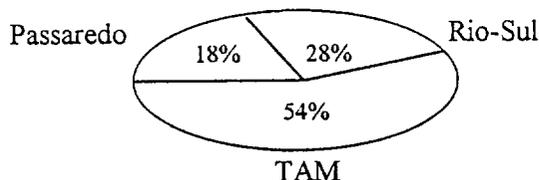


In this paper, like a brief case-study, we are going to show an analysis to the check-in area. Nowadays, each airline has its exclusive check-in counter (of attendance). Through some sceneries, we intend previously see the conflict points and, after that, to identify the best operational options.

There are two simultaneous flights, with different passengers' arrival distribution, the destinies are also different. The scenery points for the increase of the capacity of the flight, be for aircraft change, be for offer of larger number of seats in the scale. To Rio-Sul it would start to operate with the jet EMB-145, enlarging the offer from 30 to 45 places. TAM, with the F100, would pass of the offer of 30 places for 60 in its flight. The average time of attendance would be maintained the same (90 seconds). Two situations will be analyzed:

(1) Individual Check-in - staying the current system or
(2) Shared Check-in - both positions assisting to the two flights of different companies.

## Table 2 - Computational Results

| Situation | Maximum Line Size (#pax) |
|---|---|
| Rio-Sul (individual check-in) for 30 pax | 10 |
| TAM (individual check-in) for 30 pax | 6 |
| Shared Check-in for 60 pax | 7 |
| Rio-Sul (individual check-in) for 45 pax | 22 |
| TAM (individual check-in) for 60 pax | 30 |
| Shared Check-in for 105 pax | 25 |

In function of the concentrated arrival distribution of the Rio-Sul flight, a larger line size is observed in its counter, since the average time of attendance is the same for both companies. The shared use of the counters increases the global efficiency of the system. The scenery of increased demand worsens, significantly, the problem. Length of lines with 22, 30 and 25 passengers represent waits of up to 45 minutes. Possibly, this situation would delay the schedules of flight departures.

In an analysis of that type it is possible easily to simulate a situation considering a new attendance position (the counter today reserved for Passaredo) maintaining the same attendance time. The result improves considerably (see Table 3).

## Table 3 - Result with 3 Counters

| Situation | Maximum Size of Line (#pax) |
|---|---|
| Two counters (shared) for 105 pax | 25 |
| Three counters (shared) for 105 pax | 12 |

Several other studies could be accomplished, for example, the consequences in the size of lines in case it is obtained a reduction of the time of attendance etc. In this case being enough the introduction of that information and executing the program.

## Figure 2 – An Animation Tool
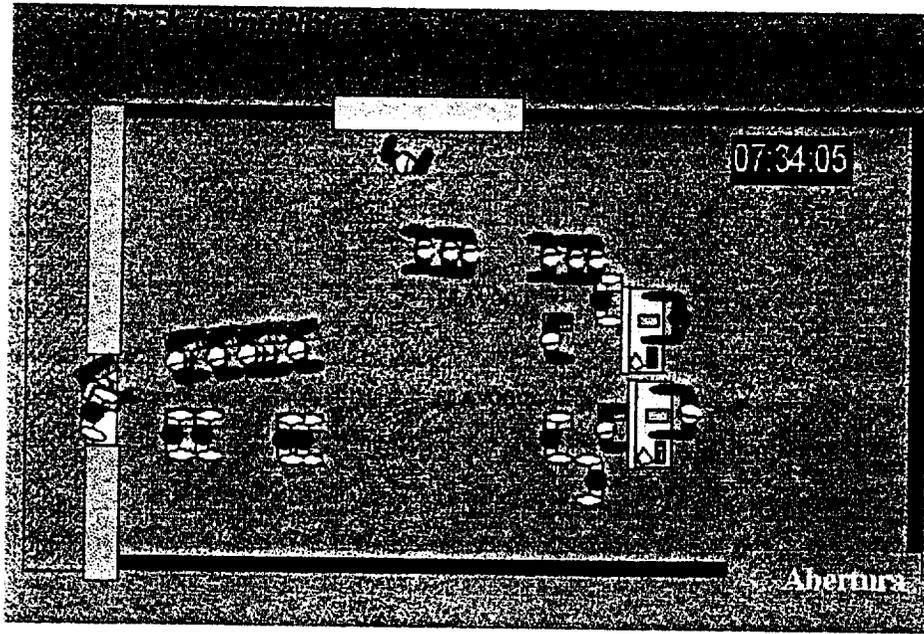
## 4 CONCLUSIONS

In this work a usefulness tool was introduced. The main users are operators of airports, office-managers of airlines in airports and other users of airports components belonging to public entities (agents of the Federal Police, Customs etc.) or private sectors (commercial points and others services like: mail, phone, snack bars and restaurants etc.). It is possible, simulating sceneries or situations, to test alternatives that come to minimize existent or potential problems, in a fast and an economic way.

This research is in developing, presently templates are being elaborated to facilitate the use of the program.

There will be the need to dispose of a big amount of information. Data like attendance time and arrival distribution of the passengers in the component will be very important in each analysis.

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# MULTIMODAL AIRPORT ACCESS IN JAPAN

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# 1 INTRODUCTION

In 1995, the authors wrote a paper entitled "Airport Access in Japan"(1995). In that paper, we discussed the institutional background of the access problems, such as the number of airports and their classification, high land prices and the absence of the concept of eminent domain, and the fine divisions of administration among the Ministry of Transport (MOT), the Ministry of Construction (MOC) and local governments. Then, we tried a few cross-sectional analyses and found the following results:

1) The share of private automobiles in the airport access depends on the size of the mother city.

2) Though the modal choice was basically determined by relative costs, the share of private automobiles tends to be smaller than calculated cost differences.

3) The above irregularity is considerably corrected by adding parking charges to the cost of private automobiles.

4) If a policy-maker wants to increase the patronage of mass transit access because of congestion and/or environmental protection, an increase in parking charges at the airport would be the quickest and the most effective method.

These conclusions were tentative and we decided to restudy the problem again to strengthen our case, using the data that have become available after the previous research was done.

# 2 CONCEPTUAL FRAMEWORK

## 2.1 Data

We use the data from Unyusho Kokukyoku (1996). This report is based on questionnaires to all the passengers on domestic flights on a single day of a year, October 25, 1995. Similar questionnaires have been collected for every other year.

The questionnaire was composed of 14 questions: 1) the airport from which the respondent departed, 2) where he originated his trip, 3) the ground transportation he took to the airport, 4)his immediate destination airport , 5) the need of transfers and the final destination

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airport, 6) the destination of his trip, 7) the first ground transportation he would take upon arrival at the destination airport, 8) the purpose of the travel, 9) duration of the travel, 10) for international passenger, the international transfer airport, 11) the number of companions, 12) the number of send-offs, 13) the reason for using air on this travel, 14) personal information (sex, age, address, occupation)

Regarding ground transportation, six choices were presented in the questionnaire. 1) *Shinkansen*, 2) Japan Railway (JR), 3) private railway or subway, 4) monorail, 5) bus or streetcar, 6) chartered bus or sightseeing bus, 7) taxi or hired limousine, 8) private automobile, 9) company car or official car, 10) rent-a-car, 11) ship or hovercraft, 12) others, 13) unknown

The data have many deficiencies for use in research as will be stated later.

## 2.2 Premises and assumptions of the analyses

1) Japan has some 90 airports altogether, including those located on isolated islands. We limited our analyses to 46 airports that have sizable number of passengers with scheduled flights. Table 1 shows those airports that we chose to analyze, classified by the number of passengers and access modes that are most used.

   A few explanatory notes are necessary about table 1. Data do not include international passengers who, therefore, are excluded from our analyses. That is why the number of passengers of reported by Narita and Kansai is small.

   In 1995 when the data was taken, there was no monorail access to the Osaka Airport and no JR access to the Miyazaki Airport. So these two airports are not listed in the rail category.

2) We assume in our analyses that the money cost of private automobile access is the average gasoline cost per a unit of time multiplied by the average time needed between the central railroad station and the airport, plus one-half of 24 hour parking charge at the airport. We assume that the cost of the bus access is the fares listed in bus schedule and that the cost of taxi access is as listed in airline time tables as the average (gratuity

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Table 1 The classification of airports by main access mode and the number of

domestic passengers

(million)

| | Mode/the number of passengers | More than 10 | 9-3 | 3-1 | Less than 1 |
|---|---|---|---|---|---|
| **Rail** | Rail/Private auto | | | Narita | |
| | Rail/ Bus | Tokyo | | | |
| | Rail/ Chartered bus | Shin-Chitose | Kansai | | |
| | Rail/ Taxi | Fukuoka | | | |
| **Bus and taxi** | Regular bus/Taxi | Osaka(Itami) | | | |
| | Chartered bus/Taxi | | Naha | Hakodate | Misawa |
| **Private auto** | Private Auto/ Regular Bus | | Kagoshima Nagoya | Nagasaki Hiroshima Komatsu Oita | Kushiro Nakashibetsu Monbetsu |
| | Private auto/ Chartered bus | | | Sendai Akita Aomori | Asahikawa      Yamagata Memanbetsu   Fukushima Yamaguchi-Ube Hanamaki Izumo         Iwami Okayama |
| | Private auto/ Taxi | | Miyazaki | Matsuyama Kumamoto Kohchi Takamatsu Tokushima Toyama | Niigata Yonago(Miho) Shonai Tottori* Matsumoto Kitakyushu Nankishirahama |
| | Private auto/ Public car | | | | Obihiro Wakkanai |

*Tottori has exactly the same share of taxi and chartered bus passengers and therefore it could be in either categories.

Source: Aviation Administration of Ministry of Transport, *Koku Ryokaku Dotai Chosa Houkokusho*, March 1996; Japan Transport Economics Research Center, *Chiiki Kotsu Toukei Nenpou*, Fiscal 1996.

are not included) .

3) The parking charge accounts for 63.6 percent of the cost of private auto access on the average: 84.5 percent for the large airports with more than 10 million passengers and 47.4 percent for other airports with less than 10 million passengers. The fact that

parking charges at 19 local airports are free and that often discount rates are available after six or seven hours, reduces the figure for smaller airports. The parking charge at the airports in metropolitan areas is high, reflecting high land prices, making private auto access much more expensive. Thus, wherever rail access, such as JR, private railway, subway and monorail is available in large metropolitan airports, their passenger shares are extremely high, as is shown later.

4) We defined the mother city of an airport as the city that has the largest share of passenger origins, and then calculate travel cost and time from its central railroad station to the airport. In cases where two cities have more or less equal shares, we simply take the average of two cities. If we apply this rule strictly, the mother city of the Narita Airport would be Narita City, but, judging from how the airport is being used, we defined Tokyo as the mother city of the Narita Airport.

5) Thus defined, the access costs of travel to the airport and from the airport should be the same, and yet the share of auto access is larger in outgoing traffic than in incoming, except at the Nagoya Airport. The reasons are not clear. Incoming passengers might be more tired, have heavier luggage and find it simpler to use taxis, or else the car was being used by other members of the family in stead of sitting in the airport parking lot.


## 3 MODELS AND RESULTS OF CALCULATION

### 3.1. Travel Cost

We used simple regression equations as below:
$$Y = \alpha + \beta \ln(\text{cost}) \qquad (1)$$
where Y is the share(%) of the access of each mode and $\alpha$ is the constant term: $Y_1$ for the share in outgoing passengers and $Y_2$ for incoming passengers.

We calculated nine equations for each, and the results of the calculations are shown in table 2 for $Y_1$ and table 3 for $Y_2$. In both tables, all of $R^2$ figures are low and most of t-values are small. Thus, we can not explain the access share by the cost only. Yet a few comments on the results are in order.

[Table 2]

1) Some regression coefficients are positive and therefore theoretically insignificant.

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2) The number of samples is small in the case of large airports (n=6) and thus $R^2$ figures are very low as we expected.

### Table 2 The cost coefficient: from the central station to the airport

|  |  | Entire airports | Large airports | Local airports |
|---|---|---|---|---|
| Private auto | Parameters (t-value) | -8.162 (-5.75) | 3.178 (0.22) | -6.310(-3.47) |
|  | $R^2$ | 0.429** | 0.012 | 0.241** |
| Bus | Parameters (t-value) | 1.452( 0.55) | -16.004(-1.54) | 8.340 (4.29) |
|  | $R^2$ | 0.007 | 0.373 | 0.326 |
| Taxi | Parameters (t-value) | -5.430(-3.48) | -1.236(-0.49) | -6.956(-3.81) |
|  | $R^2$ | 0.216** | 0.055 | 0.277** |

Note:* indicates significant at 0.05 level,  ** indicates significant at 0.01 level.

3) For the entire group of airports, coefficients for private auto and taxi are negative, and t-values are larger.    $R^2$ figures become lower in private auto, taxi and bus in that order. These results may reflect that the auto access is most cost elastic, and also that in local airports public transportation is not convenient.

4) For buses, $R^2$s are low and coefficients are irregular.   This again reflects the inconvenience of bus use at local airports, and also it seems to reconfirm the researches done previously reporting the low price elasticity of public transport.

5) Coefficients for taxis are negative in all cases and to that extent cost explains its share.

### Table 3 The cost coefficient: from airports to the central railroad stations of the mother city

|  |  | Entire airports | large Airports | Local Airports |
|---|---|---|---|---|
| Private auto | Parameters (t-value) | -5.408(-4.95) | -4.421(-1.32) | -3.156(-2.07) |
|  | $R^2$ | 0.358** | 0.302 | 0.101* |
| Bus | Parameters (t-value) | 4.438(2.85) | -18.481(-1.49) | 8.297(4.05) |
|  | $R^2$ | 0.156** | 0.356 | 0.302** |
| Taxi | Parameters (t-value) | -5.551(-3.27) | -1.544(-0.59) | -6.853(-3.46) |
|  | $R^2$ | 0.195** | 0.080 | 0.240** |

Note:* indicates significant at 0.05 level,  ** indicates significant at 0.01 level.

[Table 3]

1) The parameters of the private auto have negative values, but $R^2$ figures are low. Therefore, its share cannot be explained by the cost alone.

2) For buses $R^2$s are low and coefficients irregular as in the table 2, so we judge that the passenger share and the level of fares are not correlated.

3) Coefficients for taxis are all negative, and fits are better for entire airports and local airports than for large airports.

If one compares figures in table 2 and 3, one would recognize that the $R^2$ of private autos for entire airports is lower in table 3. For example, those passengers who were seen off at airports have to take public transportation on their return. Even if private auto is the best mode to take home, he may not be able to choose it.

Those passengers who are picked up at the airports answered private auto in the questionnaire, however their parking charges were much lower than we assumed in this research. Kiss-off passengers are one of the big reasons why $R^2$ is lower in the table3.

Looking at $R^2$, t-values, and the regression coefficients at local airports, we find that the cost of taxis from the central station to the airport affects the access share more than that of taxis from the airport to the central station. Taxis may be tangled in traffic congestion, and thus many people in urban areas have a tendency to use rail access to insure being in time for the flight. On the other hand, the people going from the airport to the city by taxi need not worry about being lost. Sightseers and the people with heavy luggage are willing to pay more for comfortable services.

### 3.2 Time variable

Air travelers are assumed to be highly sensitivity about time. Theoretically, time is a variable as important as money cost. We tried hard to include time variables into our calculation, but the regression results were not significant. We think that it was because of data restriction, especially our assumption concerning the origins of the trips, at central

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railroad stations instead of individual houses.

## 3.3 Other variables

We attempted to employ other variables to improve our calculations. We assumed that the auto share would be influenced by the existence of other modes and by how convenient they were. When the level of convenience improves in other modes, the auto share would decrease.

1) Availability of rail access

At the time when questionnaires were collected, rail access was available at Shin-Chitose, Tokyo, Narita, Kansai and Fukuoka. However there were a number of answers at Yonago and Kitakyushu of using JRs even though the systems had no airport terminus. Presumably the people walked from the JR stations to the airports, and since there was no choice of "walks" in the questionnaires, they probably answered JRs. Wherever the rail access is available, its share is very high. So we employed a rail dummy, namely 1 was available: 0 was not available, Yonago and Kitakyushu were included in the available side.

2) The level of convenience of the bus service.

There are two types of bus services: one type is timed for departures and arrivals, and another, consists of regular scheduled buses several times per hour. The problem of the former is that the bus, to allow for traffic congestion, tends to be scheduled to have ample time at the airport. As a result, the people often have to wait for a long time at the airport for airplane departure. On the other hand in the case of regularly bus service, people can choose the most convenient bus for their purpose. Thus, we put the convenience dummy, the latter=1, the former=0. The questionnaires lacked questions about the purpose of travel, therefore, we could not see the pattern of bus use, for business or non-business travelers.

We again tried to explain access shares by the linear regression model with dummy variables:

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$$Y = \alpha + \beta_1 \ln(\text{cost}) + \beta_2 rail + \beta_3 conv \qquad (2)$$

where $Y_1$ is the access share of public transportation (that includes bus, taxi, railroad and boat) from the central station to the airport and $Y_2$ from the airport to the central station; *rail* is the rail dummy, *conv* is the convenience dummy. For the Oita Airport, where 19.0 percent of the passenger use hovercrafts, we judged it should have the convenience dummy

**Table 4 Regression results for the model**

|       | $\alpha$ | ln(cost) | rail access | Convenience | $R^2$ |
|-------|----------|----------|-------------|-------------|-------|
| $Y_1$ | -24.702  | 9.336**  | 10.642*     | 6.049       | 0.709 |
|       | (-2.10)  | (4.77)   | (2.64)      | (1.29)      |       |
| $Y_2$ | -2.468   | 6.604*   | 5.952       | 4.185       | 0.376 |
|       | (-0.16)  | (2.49)   | (1.09)      | (0.88)      |       |

1. Since available modes are different for each airport, we calculated each share as an independent variable and then summed them up for $Y_1$ and $Y_2$. The coefficients in equations are in the table 4.

By adding two dummy variables $R^2$ is improved considerably. For $Y_1$, when the cost of auto access increases (namely through parking charges at the airport), the share of public
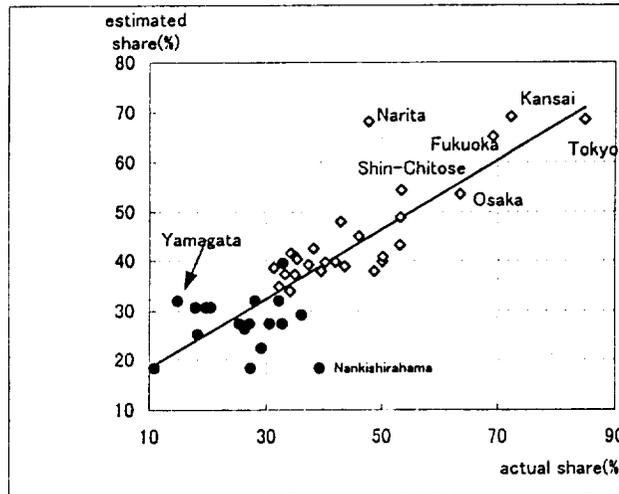


**Figure 1 Comparison of estimated share and actual share**

Airports dotted with &bull; have free parking

transportation rises. In contrast, $Y_2$, even if rail or regular bus accesses are available, the people are insensitive to the relative cost. The travelers will choose taxis, 1) when they have luggage, 2) when they do not know the exact location of their destination, 3)when they have to wait for a long time for a bus.

Figure 1 compares the shares of public transportation estimated by the regression equation with actual shares. The small airports with free parking are shown in the lower left and large airports are shown in the upper right. For example, the parking charge at the Kansai airport is extremely high and the estimated share of public transportation is 69.0 percent while the actual share is 72.2 percent. There are some irregularities and, to that extent, other factors contribute to the choice of public transportation.

## 4 PROBLEMS OF DATA AND OUR APPROACH

$R^2$s in our regressions are low because we lumped airports together that are, in fact, very different from each other. However data limitations also contributed to them. Data could be improved by amending questionnaires for the next data collection.

1) Divide the private auto question into driving and leaving the car at the airport, and "drop-offs".

2) Add an item "walking to the airport" as access method.

3) The data on travel purpose was collected on routes. In order to do our kind of research, data should also be taken at the airports.

4) Include questions concerning the number and size of luggage.

5) In the case that parking charges at the airport is very high, private parking near and around the airport becomes economically viable. Thus parking charges at the airport may not represent the real cost. We need the data concerning charges at private parking lots.

## 5 CONCLUSION

It is difficult to explain the access modal choice by cost only. In order to improve our results, we need to add more variables. But to do so, we have to have data improvement.

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However incomplete our research is, we found a few policy implications:

1)In order to improve access to airports, we have to build rail accesses.

2)Under Japanese condition, the patronage of rail access in urban areas is high and inelastic.   This means rail access will be used.   Appendix 1 and 2 are shown the access shares of major airports in Japan and the United States.

3)If one wants to increase the patronage of rail access even further, the answer is to raise the parking charges at the airport.

4)To increase the level of bus services, frequent scheduled buses are more important than other types of bus services.

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# Appendix 1 Access share to the airports and from the airport (%)

| airports | To the airports | | | | From the airports | | | |
|---|---|---|---|---|---|---|---|---|
| | auto | taxi | bus | rail | auto | taxi | bus | rail |
| Osaka | 14.2 | 20.1 | 43.4 | | 12.4 | 17.8 | 52.0 | |
| Kansai | 6.5 | 2.7 | 13.1 | 53.9 | 4.0 | 3.3 | 13.3 | 47.2 |
| Fukuoka | 12.7 | 14.4 | 7.7 | 47.0 | 8.5 | 18.6 | 9.6 | 44.6 |
| Narita(Shin-Tokyo) | 35.4 | 12.3 | 7.2 | 28.2 | 7.7 | 12.0 | 10.0 | 8.4 |
| Tokyo | 5.3 | 5.8 | 6.8 | 72.2 | 4.3 | 4.9 | 11.3 | 66.7 |
| Shin-Chitose | 10.9 | 5.1 | 10.7 | 37.6 | 7.9 | 4.4 | 10.7 | 41.2 |
| Wakkanai | 33.5 | 11.7 | 6.6 | | 22.3 | 25.9 | 15.7 | |
| Kushiro | 25.1 | 10.8 | 26.4 | | 13.9 | 8.7 | 17.4 | |
| Hakodate | 22.5 | 22.8 | 12.1 | | 10.6 | 17.6 | 10.5 | |
| Asahikawa | 36.5 | 14.2 | 16.4 | | 24.4 | 14.2 | 20.4 | |
| Obihiro | 52.4 | 4.4 | 13.5 | | 27.3 | 6.0 | 16.4 | |
| Nakashibetsu | 48.4 | 11.8 | 15.5 | | 34.9 | 8.9 | 15.8 | |
| Monbetsu | 41.4 | 6.9 | 25.9 | | 33.3 | 11.7 | 20.0 | |
| Memanbetsu | 35.5 | 4.3 | 16.2 | | 20.4 | 3.4 | 13.2 | |
| Aomori | 28.1 | 18.6 | 14.6 | | 16.0 | 22.5 | 24.8 | |
| Misawa | 18.1 | 21.9 | 10.3 | | 13.1 | 30.1 | 17.3 | |
| Hanamaki | 30.0 | 14.1 | 18.1 | | 18.4 | 11.7 | 16.0 | |
| Sendai | 28.4 | 8.9 | 22.4 | | 20.0 | 10.8 | 27.0 | |
| Akita | 32.0 | 8.4 | 19.7 | | 22.5 | 8.7 | 25.9 | |
| Yamagata | 33.6 | 8.4 | 6.4 | | 18.6 | 26.4 | 18.9 | |
| Shonai | 52.0 | 14.5 | 10.9 | | 35.7 | 18.7 | 17.7 | |
| Fukushima | 31.0 | 6.5 | 13.2 | | 25.3 | 8.4 | 27.1 | |
| Niigata | 25.1 | 30.1 | 18.6 | | 10.8 | 30.8 | 30.7 | |
| Toyama | 42.1 | 22.7 | 11.4 | | 26.8 | 27.0 | 19.4 | |
| Komatsu | 29.8 | 16.4 | 25.5 | | 23.0 | 17.7 | 36.6 | |
| Matsumoto | 46.5 | 16.8 | 13.7 | | 24.4 | 19.4 | 13.0 | |
| Nagoya | 26.3 | 14.6 | 28.2 | | 27.4 | 13.8 | 27.6 | |
| Nankishirahama | 46.1 | 30.4 | 8.8 | | 28.0 | 28.0 | 17.3 | |
| Tottori | 40.4 | 20.0 | 9.2 | | 17.9 | 32.8 | 13.8 | |
| Yonago(Miho) | 28.7 | 20.5 | 10.8 | 1.6 | 15.4 | 34.7 | 15.9 | 0.5 |
| Izumo | 26.0 | 16.3 | 19.8 | | 19.1 | 21.1 | 25.6 | |
| Iwami | 30.6 | 7.5 | 3.4 | | 16.9 | 11.6 | 12.2 | |
| Okayama | 40.0 | 11.2 | 15.9 | | 31.1 | 11.9 | 32.9 | |
| Hiroshima | 24.1 | 7.1 | 38.9 | | 19.1 | 7.8 | 38.0 | |
| Yamaguchi-Ube | 32.1 | 18.4 | 7.9 | | 24.4 | 24.2 | 15.6 | |
| Tokushima | 43.5 | 28.9 | 10.5 | | 29.5 | 25.8 | 14.4 | |
| Takamatsu | 34.2 | 26.5 | 17 | | 22.2 | 28.5 | 20.4 | |
| Matsuyama | 27.0 | 37.2 | 15.9 | | 18.9 | 42.3 | 18.2 | |
| Kochi ´ | 40.4 | 21.1 | 19 | | 28.6 | 22.4 | 26.9 | |
| Kitakyushu | 22.0 | 39.0 | 7.8 | 6.4 | 10.2 | 21.9 | 16.6 | 3.7 |
| Nagasaki | 25.8 | 8.9 | 29.3 | | 19.2 | 8.6 | 37.5 | |
| Kumamoto | 40.6 | 17.8 | 17.5 | | 29.6 | 19.0 | 20.7 | |
| Oita | 23.1 | 10.3 | 20.8 | | 12.5 | 8.9 | 26.9 | |
| Miyazaki | 37.7 | 22.8 | 15.3 | | 21.5 | 24.4 | 24.6 | |
| Kagoshima | 34.1 | 8.4 | 26.6 | | 24.9 | 8.8 | 37.8 | |
| Naha | 19.0 | 30.4 | 3.8 | | 10 | 30.6 | 6.9 | |

**Appendix 2 Access Share to the airports and from the airports in the United States (%)**

| | Auto | Rental car | Taxi | Other on-demand | Bas/van | Courtesy vans | Rail |
|---|---|---|---|---|---|---|---|
| Cleveland Hopkins | 73.4 | 11.2 | 5.0 | -- | 3.0 | 3.0 | 2.8 |
| Philadelphia | 49.0 | 18.0 | 5.0 | 13.0 | 5.0 | 3.0 | 2.0 |
| Washington National | 33.0 | 11.0 | 36.0 | 3.0 | -- | 6.0 | 9.0 |
| Atlanta Hartsfield | 60.0 | 15.0 | 7.0 | -- | -- | -- | 9.3 |
| Chicago O'Hare | 47.0 | 9.9 | 14.8 | 15.1 | 4.6 | 4.5 | 3.8 |
| Washington Dulles | 58.0 | 18.0 | 14.0 | -- | 5.0 | 5.0 | -- |
| Boston Logan | 40.1 | 14.0 | 18.2 | 12.8 | 4.2 | 1.9 | 5.8 |

Source: U.S. Department of Transportation (1996), pp.165-166.

# MULTIMODAL AIRPORT ACCESS IN JAPAN

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## ABSTRACT

In this paper, the authors intend to analyze factors that affect access modal choice in Japan. Most airports, excepting very small ones, in Japan have multimodal access: by bus and private automobile.  A few large airports-Kansai, Narita, Haneda, Shin-Chitose, Fukuoka and Osaka – have rail access also.

We weighted quantitatively relative significance of money cost, travel time and other factors that were assumed to determine the modal choice.  Because of limitations of available data and because of differences among individual airports, our cross-sectional approaches to the access share had somewhat lower fits than we had hoped for. Nevertheless our findings seem to have a few policy implications.  For example our research revealed that parking charges at airports were a crucial factor in access modal choice in Japan and so, if one wants to increase the patronage of mass transport, increase in parking charges for private automobile seems most effective.  We want to comment on other factors also.

# PLANNING SURFACE ACCESS PROVISION AT MAJOR AIRPORTS

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# 1 INTRODUCTION

Air travel in Europe is growing at a faster rate than any other means of transport, typically 6% per annum despite economic recessions in several countries. The recent deregulation of air transport in Europe could well accelerate this process. However, surface transport systems which serve the airports, particularly roads, are not keeping up with this increased demand for capacity. This is not just a question of the money not being available for investment in new roads. Many governments, national and local, are questioning the sustainability of unconstrained road building and in some cases are already acting upon this by cutting their construction progr....mes.

It is within this context that the Airport Regions Conference, a Pan-European network of regional councils, was founded in November 1995. All the regional councils have the common feature of a major international airport within their boundaries, often serving a city outside of the regional boundary. The network has set up four working groups to address issues arising from the day to day operations of major airports and the forward planning of airport expansion. One of these groups is dealing with surface access to the airport and this presentation is submitted on behalf of this group with its agreement.

# 2 AIMS AND OBJECTIVES

It would be helpful to explain the aims and objectives of the working group. These are;

1. To establish the surface access characteristics of the individual regions' airport.

2. To exchange information with each other with a view to a better understanding of the way in which air passengers and airport employees make trips to and from the airport.

3. To compare surface access facilities provided at airports, e.g. highway, rail, bus, in order to plan future facilities in a better way in conjunction with the airport operators.

4. To set targets for increased proportions of air passengers and airport employees travelling to and from the airport by public transport.

5. To examine the current and future role of High Speed Trains both as national and international feeders to major airports and as an alternative to certain air journeys of up to, perhaps, 800 kilometres.

6. To commission research into relationships between the characteristics of air passengers, their journey purpose, surface journey length and modes available and similarly for employee journeys to and from work at the airport .

# 3 SURFACE ACCESS CHARACTERISTICS OF AIRPORTS

## 3.1 Data Collation

Member regions have collated information about the existing surface access characteristics of their airports, altogether 18 in number. This information includes;

- distance from airport to the city centre.
- transport links to the nearest city, by all modes with journey times, frequency , cost, etc.
- transport links to the rest of the region, by all modes with journey times, frequency , cost, etc.
- proportion of air passengers using the different modes of surface access.
- planned infrastructure links to the airport.

In analysing this information, the results have been categorised into three ranges of airport;

- Category 1; those with more than 20 million air passengers per annum and 20,000 employees on the airport.
- Category 2; those with 10 to 20 million air passengers per annum and 10,000 to20,000 employees on the airport.
- Category 3; those with less than 10 million air passengers per annum and less than 10,000 employees on the airport.

## 3.2 Distance from airport to city centre

The average distance was found to be about 20 km, with Category 1 airports being slightly greater at 22.4 km, Category 2 at 19.1 km and Category 3 at 18.7 km, notably small differences. However, 3 airports were more than 40 km away, whilst 4 were 11 km or nearer. Table 1 sets out the variations between distances and passenger throughputs for the airports examined, together with their category. In general, the airport distance increases with the number of passengers. However, there are exceptions which are replacements of older airports nearer the city [Stockholm-Arlanda, Milan-Malpensa] which anticipate greater throughputs and the constraint of existing city infrastructure [London-Gatwick].

TABLE 1

| Airport | Category | Air Passengers [1995 Mppa] | Distance to main city centre [Km] |
|---|---|---|---|
| London-Heathrow | 1 | 52 | 25 |
| Paris-CDG | 1 | 28.7 | 23 |
| Paris-Orly | 1 | 26.6 | 14 |
| Amsterdam-Schipol | 1 | 21 | 10 |
| Gatwick | 1 | 21 | 40 |
| Manchester | 2 | 15 | ₁2.5 |
| Düsseldorf | 2 | 14 | 8 |
| Munich-F.J. Strauss | 2 | 13.5 | 28.5 |
| Stockholm-Arlanda | 2 | 13.3 | 42 |
| Barcelona-El Prat | 2 | 11.7 | 13 |
| Brussels-Zaventem | 2 | 11.2 | 10.7 |
| Vienna | 3 | 7.5 | 20 |
| Helsinki-Vantaa | 3 | 7.2 | 18 |
| Glasgow | 3 | 5.5 | 15 |
| Cologne-Bonn | 3 | 4.7 | 16 |
| Milan-Malpensa | 3 | 4 | 40 |
| Liverpool | 3 | 0.5 | 12 |
| Lelystad* | 3 | 0 | 10 |

* No passengers, airport not open for commercial operations.

## 3.3 Public Transport links to the city centre

Some of the airports are served by more than one choice of public transport mode. For the purposes of this analysis, the one offering the best combination of frequency, transit time and cost has been selected.

### 3.3.1 Service Mode

Rail is the main mode in the case of all Category 1 and 2 airports, with the exception of Stockholm-Arlanda, but even here a high speed rail link is under construction with completion expected late 1998. However, the form of the rail connection to the city centre varies considerably, including subway, special links and special trains on the local network. Services can also include regional trains, long distance trains and high speed trains are becoming a feature in some cases. These latter not only offer intermodality with air travel for regional and national connections but can be a competitive alternative for journeys up to, perhaps, 800 kms. In the case of category 3 airports, bus is the predominant mode as the lower demands and generally closer distances to city centres do not warrant the investment of a railway.

## 3.3.2 Service Frequency

In most cases, services started at about 5 or 6 a.m. and finished at about 11 p.m., regardless of airport size. However, the frequencies varied greatly, with Category 1 airports having intervals of no more than 7 or 8 minutes and as little as 3 or 4 minutes at certain times. Category 2 had intervals of 15 to 20 minutes typically whilst Category 3 where generally 20 to 30 minutes with one case of 60 minutes. Clearly there is a relationship between demand and service provision, but intervals of greater than about 20 minutes will be unattractive in competition with taxis and private cars. Therefore, it may be necessary to subsidise a frequent service until patronage builds up if private transport usage is to be constrained. Table 2 shows the minimum service interval and "best" public transport mode.

TABLE 2

| Airport | Category | "Best" public transport mode | Minimum public transport interval [Mins] | Minimum public transport travel time [Mins] | Fare rate fare per 10 Km [ECU] |
|---|---|---|---|---|---|
| London-Heathrow | 1 | Subway | 3 | 40 | 1.6 |
| Paris-CDG | 1 | Train | 7.5 | 29 | 3.0 |
| Paris-Orly | 1 | Train/shuttle | 5 | 30 | 5.9 |
| Amsterdam-Schipol | 1 | Train | 7.5 | 15 | 2.9 |
| Gatwick | 1 | Train | 4 | 30 | 2.3 |
| Manchester | 2 | Train | 15 | 17 | 2.3 |
| Düsseldorf | 2 | Train | 20 | 12 | 1.9 |
| Munich-F.J. Strauss | 2 | Train | 20 | 38 | 2.5 |
| Stockholm-Arlanda | 2 | Bus | 5 | 30 | 1.7 |
| Barcelona-El Prat | 2 | Train | 30 | 24 | 1.7 |
| Brussels-Zaventem | 2 | Train | 20 | 18 | 1.8 |
| Vienna | 3 | Train | 30 | 35 | 1.3 |
| Helsinki-Vantaa | 3 | Bus | 20 | 30 | 1.5 |
| Glasgow | 3 | Train/shuttle | 10 | 18 | 1.2 |
| Cologne-Bonn | 3 | Bus | 15 | 20 | 2.6 |
| Milan-Malpensa | 3 | Bus | 30 | 50 | 1.5 |
| Liverpool | 3 | Bus | 30 | 40 | 2.0 |
| Lelystad* | 3 | Bus | 60 | 10 | 1.7 |

## 3.3.3 Transit Times

The average city centre transit time was just under 30 minutes, but travel times ranged from 10 to 50 minutes. This usually depended upon distance and mode, but not always. In some cases trains times were exceptionally slow because subway or suburban services were being used [London-Heathrow, Paris-Orly, Vienna] whilst buses could be relatively

fast where use is made of motorways [Stockholm-Arlanda]. Generally speaking bus services have to use congested city road networks and offer unattractive journey speeds. All three airport Categories displayed similar characteristics with transit times ranging from about 15 to 40 minutes and averages of about 25 to 30 minutes. This would appear to be generally acceptable with passengers and so more distant airport locations need higher speed rail or dedicated bus services to keep journey times to this range. Table 2 sets out the minimum travel time and city centre distance.

### 3.3.4 City Centre Travel Cost

The cost rate per 10 km for Category 1 airports ranged from ECU 1.5 to ECU 5.9, averaging ECU 3.1 at 1995 prices. For Category 2 the equivalent figures were ECU 1.7, ECU 2.5 and ECU 2.0. In the case of Category 3 the range was ECU 1.2 to ECU 2.6, averaging ECU 1.7. Hence generally speaking, the busier the airport, the higher the fare rate charged per 10 kms. If the actual fare cost is examined, a similar conclusion is reached, with Category 1 airports averaging ECU 6.3, Category 2 ECU 4.0 and Category 3 ECU 3.1. Given that the three categories of airport are roughly the same average distance form the city centre [see section 3.2 above] it is probable that the busier airports have a higher fare cost to reflect a better level of public transit service. Table 2 shows the public transport fare rate per 10 km for each airport.

### 3.4 Public transport links to the surrounding region

Whilst links to the main city centre concerned are important, all airports also serve their region. If the amount of private car traffic is to be managed in the future, regional links should include public transport, preferably rail as travel distances are likely to be longer than to the city. In the case of the 18 airports examined all but three had direct rail or bus linkages to other parts of the region, Vienna, Liverpool [England] and Lelystad [Netherlands] being the exceptions, the latter not being fully operational as yet. Generally speaking, the busier the airport the more comprehensive the network of services and choice of mode. As in the case of the lower demands for travel between the city centre and less busy airports, it may be necessary to subsidise regional services until patronage has reached viable levels. Buses offer relatively low cost options. However, where new airport locations are being considered, proximity to a rail network should be an essential requirement, preferably with opportunities for through running rather than spur lines. Looking farther afield, 8 of the 18 airports had links to other regions or countries, with 5 by train [and maybe bus] and 3 by bus only. Paris-CDG, Amsterdam-Schiphol and London-Gatwick offer the most comprehensive levels of rail service, by TGV in the first case. Other notable examples are Manchester [England] and Milan-Malpensa which both have rail connections beyond their immediate region.

### 3.5 Road link to main city centre

Most of the airports examined have motorway or 4 lane highway connections to or close to the city centre, the exceptions being London-Gatwick, Düsseldorf, Helsinki-Vaanta and Lelystad. Average journey times were 46 minutes for Category 1 airports, 33 minutes for

Category 2 and 25 minutes for category 3. In no case is the highway dedicated to airport access, hence journeys are subjected to congestion arising from general traffic usage. Generally, the minimum off peak journey time is about 50% of the peak period journey time with average journey speeds of 52 kph and 28 kph respectively. However, there are cases where peak period journey speeds drop to as little as 10 or 11 kph! Where city centre motorway links are provided, maximum off peak journey speeds are about 80 kph, but off peak speeds can still be as low as 20 or 30 kph where there is no motorway and/or the route is subject to heavy traffic congestion. Table 3 shows the information on distance from city centre and average travel time.

**TABLE 3**

| Airport | Category | Air Passengers [1995 Mppa] | Distance to main city centre [Km] | Average travel time by road [Mins] |
|---|---|---|---|---|
| London-Heathrow | 1 | 52 | 25 | 65 |
| Paris-CDG | 1 | 28.7 | 23 | 45 |
| Paris-Orly | 1 | 26.6 | 14 | 30 |
| Amsterdam-Schipol | 1 | 21 | 10 | 12 |
| Gatwick | 1 | 21 | 40 | 75 |
| Manchester | 2 | 15 | 12.5 | 20 |
| Düsseldorf | 2 | 14 | 8 | 20 |
| Munich-F.J. Strauss | 2 | 13.5 | 28.5 | 40 |
| Stockholm-Arlanda | 2 | 13.3 | 42 | 40 |
| Barcelona-El Prat | 2 | 11.7 | 13 | 30 |
| Brussels-Zaventem | 2 | 11.2 | 10.7 | 45 |
| Vienna | 3 | 7.5 | 20 | 30 |
| Helsinki-Vantaa | 3 | 7.2 | 18 | 28 |
| Glasgow | 3 | 5.5 | 15 | 25 |
| Cologne-Bonn | 3 | 4.7 | 16 | 15 |
| Milan-Malpensa | 3 | 4 | 40 | 40 |
| Liverpool | 3 | 0.5 | 12 | 25 |
| Lelystad* | 3 | 0 | 10 | 10 |

* No passengers, airport not open for commercial operations.

### 3.6 Regional, national and international road links

Again, it is appropriate that the airport has connections with a wider area in order to serve the greatest potential market. Of the 18 airports studied, 13 have direct access to their regional and national motorway networks, with international connections in some cases. Where there are deficiencies it is generally because of missing links in the national motorway network rather than a lack of connection to the airport.

## 3.7 Modes of surface transport selected by air passengers

It is notable that city centre average journey times obtained from the examination of the 18 airports were 29, 22 and 29 minutes by public transport and 46, 33 and 25 minutes by road for Categories 1, 2 and 3 respectively. However, many factors determine mode choice and in addition to those analysed above is perhaps the most influential, convenience. Despite the apparent advantages of public transport in some cases, the following analysis shows some unexpected patterns.

### 3.7.1 Use of public transport

The range is great, from 1% at Lelystad to 41% at Munich-Strauss, with an average of 21%. Generally the Category 1 airports have the highest proportions, with a range of 23% to 36% and an average of 29%, reflecting their better public transport provisions which are mainly rail based. Category 2 airports range from 9% to 41% [average 24%] with 13% rail and 11% bus, whilst Category 3 range from 1% to 20% [average 12%] and are predominantly bus. Overall the highest percentages are achieved at Munich-Strauss, 41%, and Stockholm-Arlanda, 40% which have high frequency rail/bus and bus services respectively. Whilst these are not the busiest of the airports examined, both being Category 2, they do illustrate the proportion of public transport mode choice that can be obtained, despite both being served by motorway networks. On the other hand, it is notable that the Category 1 airports still only achieve shares of 9% to 25% rail usage, with the excellent rail services in most cases and fairly congested road networks. Clearly the convenience of using private cars is having an influence and this needs further analysis.

### 3.7.2 Use of private cars and taxis

At Category 1 airports the use of private car ranges from 38% to 54% with an average of 46%, some half as much again as those using public transport. The proportion using taxis at these airports ranges between lies between 9% and 31% with an average of 20%. The two uses are inversely correlated with each other, generally totalling about 65% between them. This would seem to indicate that taxis are a substitute for mass public transport where, for what ever reason, use of private cars for trips to and from the airport are unattractive and mass public transport is not particularly well developed. The operational disadvantage of taxis as compared with "drive and fly" private car trips is that the former, for the most part, involve double the number of surface access movements at the airport for every air passenger. In the case of Category 2 airports, private car use ranges from 38% to 54%, averaging 46% with taxi use between 8% and 24% averaging 14%. However, in these cases the inverse correlation between car and taxi use does not appear to exist, the two uses totalling between just over 50% to nearly 80%. The taxi use seems, in these cases, to be more affected by the opportunities for taking mass transport than in the case of the Category 1 airports. At Category 3 airports private car use lies between 53% and 90%, averaging 65%, and taxi use between 1% and 26%, averaging19%. In most cases, car and taxi use are clustered around 60% and 20-25% respectively, with the exception of Lelystad with 90% car use and Helsinki-Vantaa with 72% car use. Hence private car and taxi use appears to be fairly consistent at the less busy airports, but can be influenced to some

extent by the provision ,or virtual non-existence, of bus services. Proximity to the city centre and the cost of taxis also, no doubt, have some influence.

# 4 CONCLUSIONS

## 4.1 Summary

Not surprisingly, the results differ greatly from airport to airport. For example, the proportion of air passengers using public transport varies from over 40% to only 1%. Examination of the facilities shows that this does not necessarily depend upon the excellence of the public transport services, with frequency of service ranging between 1 and 20 per hour at different airports. Typical airport to city centre journey times by public transport lie between 10 minutes and 50 minutes. On the basis of this analysis, the group has set targets for the proposed share for public transport of 30% to 50% for air passengers and 30% to 40% for airport employees.

## 4.2 The Next Stage

In order to obtain a better understanding of the relationships between air passenger and airport employee characteristics, the working group is assembling further information from surveys of these two populations from as many of the member airports as is possible. In some cases airport operators have the information and are making it available. In other cases specific surveys will have to be commissioned. Analysis of the relationships will be carried out with the results available later in 1998. The assistance of a university has been employed to undertake this work.

## 4.3 Implementation

It is intended that the results of the above work will be used to make better use of existing surface access facilities at airports as well as to plan future transport infrastructure to serve the airports. It will be for each regional council to develop the most appropriate solution in conjunction with its airport operator. There are already several cases where the regional council and the airport operator are working closely together to increase the public transport share of trips to and from the airport. Given the range of airports examined [currently through putting between 8 and 42 million passengers per annum] the results should have much wider European application and would be of interest in the World-wide context, both for those dealing with existing surface access problems or planning airport expansion.

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# Airline Economics and the Inclusion of Environmental Costs on Airport Hub Pricing: A Theoretical Analysis

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## Abstract

Previous studies into hub airports have tended to concentrate on the economic dimensions, such as market power, airline fares and barriers to entry. Airline hubbing has considerably altered airport economics: it increases the number of flights into and out of a major airport and it increases externalities such as airside and landside congestion, aircraft noise and emissions. The principal contribution of our paper is to focus on the environmental externalities associated with extensive hubbing. In the first part of the paper we present a conceptual spatial model which addresses the environmental impacts related to extensive hubbing. In the second part of the paper, we formally address the conceptual problem by proposing a model of airline economics. Schmalensee's (1977) model is adapted to allow for a monopolist airline to determine the optimal network and, to set prices and the number of flights. Finally, the paper explores the effect of charging the airline for these externalities through an 'environmental' tax when it operates a hub-and-spoke network. We examine two scenarios, a passenger-related tax and an aircraft-related tax and show the extent to which prices and the number of flights are affected by the tax.

Key words: Hub-and-Spoke Development, Environmental Costs, Airport Charges.

# 1 Introduction

Airline deregulation in the U.S.A. has altered dramatically the operational landscape of airline networks and the hub-and-spoke structure has been extensively adopted as the method of delivery (Kanafani and Ghobrial, 1985). This structure, together with hub airports, are likely to flourish around the world as a consequence of airline liberalisation in the European Union and in Asia and the growing trend toward privatization of the airline industry (Berechman and de Wit, 1997, and Chin, 1997). Airline hubbing has altered airport operations in many different ways[1]. The most striking is the increased aircraft operations at major hub airports, resulting in a surge in workload for air traffic controllers and increases in airside delays faced by passengers and airlines. Increases in aircraft operations at hub airports are not only due to increased connecting traffic but to the supply of air services which can also induce additional demand to and from the hub airport (see, e.g., Hansen, 1997). Indeed, the larger variety of nonstop destinations offered at the hub airport, as a result of economies of traffic density reached through connecting passengers, often results in a growth of origin/destination traffic. Hub airports are engines of economic growth attracting more business, investment and employment and these multiplier effects themselves boost passenger and cargo traffic. The fact that hub airports have to accommodate large banks of flight schedules, in order to handle a high volume of connecting traffic, exacerbates daily peaking, both within an airline and in competition between airlines, and adds to the problem of congestion. Efficiency in the utilization of given airport facilities would rather require aircraft operations to be spread evenly across the operating day (Hanlon, 1996), but the practical reality for airport management is increasing throughput of aircraft (for example, rapid exit taxiway) or building more runway capacity. A survey of the 100 busiest U.S.A. airports found most are building additional infrastructure to reduce either current or anticipated aircraft delays (Rutner and Mundy, 1996).

Airport expansion is thus a trade-off between economic benefits and environmental costs, and the literature on airline hubbing downplays these externalities. Although the economic impact of airline hubbing has been amply assessed by, *inter alia*, Kanafani and Ghobrial (1985), Borenstein (1989), McShane and Windle (1989), Brueckner, Dyer and Spiller (1992), and Ghobrial and Kanafani (1995), important environmental externalities due to extensive hubbing have not received enough attention. The aim of this paper is to fill part of this gap. In a more general context, it has been recently argued that the aviation industry has to take its fair share in global climate change and in ozone depletion[2] (OECD, 1997). Environmental concerns related to airport hubbing operations mainly pertain to aircraft noise and emissions (major nuisances), although there is a growing concern about issues such as aviation fuel burn -mainly due to extra circuity - and the long-term depletion of non-renewable fossil fuels, sewage and waste disposal, apron, taxiway and runway pavement run off, water quality, and fuel storage. Since these environmental externalities are proportional to the number of aircraft operations, it is clear that the development of hub-and-spoke networks has exacerbated the exposure of communities residing in the vicinity of airports to sources of nuisances.

This paper is organised as follows. Section 2.1 discusses the extent to which hub airports affect environmental externalities. A conceptual spatial model of fully-connected networks and hub-and-spoke networks together with their 'footprints of pollution' is presented in Section 2.2. The model developed in Section 3 extends the approach by Schmalensee (1977) to the case

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[1] See Kanafani and Ghobrial, 1985.

[2] Airliners represent only about 3% of the world's total energy consumption.

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where a monopolist airline operates a network and sets prices and the number of flights. The transformation of operations from a fully-connected network to a hub-and-spoke network are discussed fully in Sections 3.2 and 3.3, respectively. The resulting propositions are discussed in Section 3.4 and supported by proofs in an appendix. Some comparative static properties of our model are investigated in Section 4 by tracing the effects of exogenous variables - an aircraft-related tax and a passenger-related tax. Section 5 concludes by reiterating the main arguments in the paper and suggesting directions for further research.

## 2  The Problem and Conceptual Approach

### 2.1  The Externality Problem Related to Hub Development

Airline hubbing has been described by various researchers in transportation studies and its importance for airline economics has been largely acknowledged. Bauer (p.13, 1987) provides the following definition of this practise:

> " A hub-and-spoke network, as the analogy to a wheel implies, is a route system in which flights from many 'spokes' cities fly into a central 'hub' city. A key element of this system is that the flights from the spokes all arrive at the hub at about the same time so that passengers can make timely connections to their final destination."

Hub airports have a high percentage of connecting passengers, i.e., passengers who are travelling through, rather than to or from, the airport. Although traffic concentration at a limited number of airports is not just a post-deregulation or liberalization phenomenon, hubbing development is often associated with higher concentration and higher growth rate in traffic enplanement and aircraft movements. Table 1 (see page 23) lists the 30 largest US airports in declining order of percentage of connecting passengers. The major hub airports appear in the first group of Table 1, where more than 50 percent of the total enplanements are connecting passengers. These airports tend to be located towards to centre of the US. The top 10 airports in terms of connecting traffic accounted for about 28% of all US departures in 1994 compared to 24% in 1978, confirming the trend of higher concentration in aircraft operations (USDOT, 1978, 1994). The third and fourth columns in Table 1 indicate the growth between 1984 and 1994 in enplanements and departures, respectively. The correlation between the percentage of connecting passengers and enplanement growth is positive and equal to 0.21, while the correlation between the percentage of passengers changing planes at the airport and the departure growth is equal to 0.16 in this list.

Clearly, environmental constraints are likely to arise at any airport experiencing growth in traffic volume. In this paper, however, we argue that the problem of environmental externalities is exacerbated by hub development and that, to some extent, hubbing contributes to a spatial redistribution of externalities. Also, hub development can arise suddenly as in the case of Raleigh/Durham Airport (RDU), N.C., where departures doubled between 1986 and 1989 and enplaned passengers nearly trebled (USDOT, 1986,1989). Such dramatic and unanticipated surge in airport size, frequent during the early stage of hub development, are more likely to have disruptive effects on the community and/or on the environment than airports experiencing foreseeable and moderate growth. As the development of a hub-and-spoke system is associated with the development of banks of flights so that passengers can make timely connections, it is important to stress that both the frequency and the intensity of the aircraft nuisance events (noise plus emissions) have increased (for a given aircraft/engine technology) at hub airports.

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Hubbing encourages both increases in frequency (more flights per route) and increases in the number of routes served from a hub, as it becomes financially viable to operate direct services on smaller city-pair markets, all else being equal. The increase in the intensity of the nuisance events is due to the fact that a typical hub airline operates many large banks of flights per day, where each bank can consist of several dozen flights[3]. In other words, there is a larger flow of aircraft operations through the airport for a given time frame, ceteris paribus. Deregulation has exacerbated this phenomenon as flight scheduling differentiation has been reduced (Borenstein and Netz, 1993).

Negative social and environmental impacts of large hub airports are concentrated in the airport's immediate vicinity as those are the areas which experience increased noise and air pollution, influx of transient labour, and disruption of existing community development patterns. Communities in the vicinity of airports (residential areas, education and health facilities, places of worship, commercial and industrial areas) are directly exposed to the nuisances related to aircraft operations. The severity of this exposure depends on many factors ranging from the location of the land use with respect to the approach and departure flight paths, the mix of aircraft type (pure jet, turbo-prop, propeller), noise characteristics of aircraft (including any adopted noise abatement procedures), the direction of the wind, the type of building construction and acoustic insulation (if any), the time of occurrence during the day or night, and, of course, the number of aircraft operations. Several studies have shown that increased exposure to aircraft nuisance, in particular noise, negatively affects the property value of residential homes near an airport (see, e.g., Mitchell McCotter, 1994a). Increased exposure to aircraft nuisance increases annoyance in residents (both owners and renters) and reduces the utility of residents who live in proximity of the airport. In addition, for those residents who have to move because of compulsory land acquisition, noise also induces transaction and relocation costs as well as a loss of place-specific surplus[4]. Moreover, more frequent low overflights of neighboring land uses present an increasing potential hazard -notwithstanding the risk probabilities being extremely small - as accidents may occur along take-off and landing paths[5].

In addition to the vexing problem of aircraft impacts, there is the associated problem of vehicular traffic intrusion and road traffic noise through adjacent communities. To provide the landside road access and parking at major U.S.A. airports to cater for the dominant mode of private automobile transportation to get to and from airports, neighborhoods have been eliminated or severed. There are large vacant parcels of land adjacent to airports (e.g., Los Angeles International) with no property tax income. Additionally, strip zones and 'red light' districts may appear in areas of transient land use, further lowering residential amenity. Finally, in addition to air-side operational delays and their associated environmental issues (with increased aircraft noise and emissions from holding patterns) there are other issues related to the use of hub airport development: extra fuel burn due to the circuity of hub-and-spoke en-route operations; higher probability of fuel dumping from airborne aircraft following any major trouble with landing or take-off operations; apron, taxiway and runway pavement run off, congestion in passenger terminals and at parking lots and garages; ground access (car

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[3] As an example, American Airlines operated in 1990 up to 50 arrivals and 50 departures per flight bank and had 12 banks of flights a day at its Dallas/Forth Worth hub.

[4] See Feitelson et al., 1996, for an excellent discussion on the impact of airport noise on the willingness to pay for residences.

[5] For example, at Amsterdam Schiphol Airport (1997, p.42), which handled 343,000 take-offs and landings in 1996, safety zones have been marked around the airport area. In a small number of areas the risk of an individual dying as the result of an aircraft accident is once in every 20,000 years.

and transit) around and to the hub airport; sewage and waste disposal, water quality, and fuel storage; and, increasingly widespread, protection of endangered species near the hub airport.

The absence of straightforward market solutions with respect to environmental resources and hubbing-related externalities has several consequences. First, many of these externalities, in particular, the environmental issues, are external to the hubbing airline's own cost calculations. Externalities are not fully reflected in the airline's choice variables such as the network configuration, fares and frequencies. Second, since an airline operates a system of airports, its decision to develop a hub airport is likely to have an impact on the level of operations (traffic and frequencies) on the surrounding airports as well as on the spoke airports. If, in a region, aircraft operations are 'transferred' from some airports to a hub airport, so too would some environmental externalities be transferred[6]. This strengthens the need for the different airport authorities to consider a system of airports, at the regional, national (and sometimes international) levels, as part of an integrated strategy (Black, 1997). Unilateral local or regional policies can affect conditions of competition by discriminating among groups of airlines. Recently, Oum et al. (1996) suggest that optimal airport pricing within a system of airports should be part of an integrated strategy so that complementarities between the hub airport and the spoke airports could be taken into account in an appropriate (efficient) way. Finally, because environmental resources are not traded in markets, adversely affected parties, when seeking monetary compensation for loss of amenity or when disputing airport expansion, resort instead to lobbying, using political pressure and/or attempting to capture the regulatory process. In turn, this may be detrimental to the development and to the performance of the airline industry (Bruzelius, 1996).

Only a few airports have a genuine tax for environmental related costs, the practice being that airport managements charge airlines for their use of airports that are aligned to the services provided[7]. There is an array of instruments available to support the implementation of the 'polluter pays' principle, some of which are fully endorsed by the International Civil Aviation Organization (ICAO). The most common options are based on: (a) ICAO (1993) noise certification chapters (giving rise to so-called Stage 2 and Stage 3 aircraft noise limits); (b) ICAO noise certification level(s)[8]; (c) instrument measurements of noise levels from actual take-off, landing and overflight[9]; (d) long-term average measurements of noise and emissions levels by aircraft type; (e) a 'noise/emissions per seat' index; (f) aircraft weight; (g) flat or increasing charge per aircraft operation; (h) a ticket tax to be imposed on each ticket sold for flight to and from that airport; (i) a gate tax to be collected from all passengers using the airport; and (j) peak and off-peak, as well as day and night time period operations.

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[6]Preliminary empirical research suggests that following American Airline's 1987 hub development at RDU, all surrounding airports located within a radius of 200 km. from RDU experienced a significant drop in the number of aircraft departures and enplaned passengers throughout the 1986-1992 period. If American Airline's decision to operate a hub at RDU caused some traffic diversion from these airports then this will also affect externality costs. (For a discussion on how deregulation has affected local air services at small airports, see, e.g., Kanafani and Abbas, 1987.)

[7]Airside revenues generated from aircraft operations typically include landing fees, airport parking charges, passenger fees, terminal usage charges, terminal navigation charges, cargo handling, fuel and oil concessions, security and fire rescue charges. Landside revenues are derived from non aircraft-related commercial activities in terminals and rents from airlines and concessionaires, and correspond to around 30%-65% of total revenues depending on airports according to Kapur (1995).

[8]Each specific aircraft has three measurements that make up the ICAO noise certification levels - on take-off, on landing and from the side - with all measurements conforming to standard tests.

[9]This is measured noise on each event and may differ from the ICAO levels because of engine performance deterioration, by age, poor maintenance, etc..

Given the growing concern about environmental related issues, more and more airports specifically address the externality problem. A recent survey by Airports Council International Europe has identified 57 member airports in Europe, out of over 350, which are applying differential charges based on noise (Cameron, 1997). Perhaps the most comprehensive example of a genuine tax for environmental related costs is Sydney (Kingsford Smith) Airport (SYD), Australia, where the Commonwealth Government amended the Federal Airports Corporation (FAC) Act to direct the Corporation to carry out activities which protects the environment from the effects of aircraft operations, with the cost to be borne by the aviation industry on the 'polluter pays' principle (FAC, 1997). To this end, in addition to the aeronautical charges, SYD imposes a noise levy designed to generate sufficient revenue over a long-period of time (5 years) to fund all ameliorative measures (for example, acquisition of noise-effected residences, acoustical treatment of residences, schools, places of worship, hospitals and child care centres). Despite a recent air quality management study conducted at SYD (Mitchell McCotter, 1994b), the possibility of charging airlines for their emissions has not been considered by the Australian Federal Government, nor by the FAC, although such emissions induce non negligible costs to society (see e.g., Perl et al., 1997). It is beyond the scope of this paper to empirically assess the overall environmental impact due to hubbing development or to empirically assess the effects of a 'polluter pays' tax aiming at achieving policy objectives. We believe, however, that this sort of empirical research should be part of the future research agenda on airline economics and airport hubbing.

## 2.2 Conceptual Approach

Given the advent of hub-and-spoke (hereafter, HS) operations, we wish to know the possible impacts of including environmental costs on airport charges to hubbing airlines. To this end, we need a precise understanding of airline economics. That is, we need to understand when it is more profitable for an airline to operate a HS network instead of a fully-connected[10] (hereafter, FC) network. A crucial question is: how a move from a FC network to a HS network will affect the magnitude of aircraft movements in the system of airports (and the equivalent changes in environmental impacts on communities around the system of airports) ? In this section, a perspective of the environmental regulator is taken so as to provide the context for the detailed airline economic analyses which follow in Section 3. To do this the problem is reformulated as an existing base case situation of a FC network in which an environmental impact assessment is being undertaken to provide decision makers with comprehensive information of the costs and benefits of alternatives to cope with the expected rise in aircraft movements as a result of hubbing operations and soaring demand.

Figure 1 (see page 24) is a highly simplified spatial representation of the current situation with a FC network and its associated environmental impacts at the three airport nodes[11]. In Figure 1 the airports are represented as the solid nodes and the 'footprints of pollution' (for example, aircraft noise or the spatial dispersion and dilution of aircraft emissions) as dotted circles around the airports[12]. In this (base case) symmetric network it is assumed that the level of 'externalities' is the same at each airport as indicated by the radius of the

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[10]Also known in the literature as a linear or point-to-point network.

[11]This spatial model as a basis for considering economic and environmental aspects of airport development is described more fully in Black (1995), where it was first applied to assess the impacts on the environment of the port system in Sydney following technology change in international shipping which lead to the container revolution (see Rimmer and Black, 1982).

[12]We implicitly assume that the population distribution at each airport is identical.

circles. Although the estimations of both the spatial extent of impacts and the dose-response relationship between the amount of pollution and community response/reaction are central parts of the methodology of any environmental impact assessment (EIA), they are beyond the scope of this paper. All we need to state here is that an EIA must establish and describe fully, using well-known airport planning techniques -for example FAA Part 150 Noise Study in the U.S.A.[13] (1985) - the base environmental conditions implicit in Figure 1. A comprehensive EIA then requires: (a) the formulation of alternatives (new airports, more airport capacity, air traffic management and pricing) to meet the problem (growth in demand for aviation services); and (b) the estimation of future aircraft mix and movements and runway usage as a basis to determine environmental impacts. In Figure 2 (see page 25) the HS network with its associated environmental impacts is shown as a future option but there are three possibilities indicated: (a) whether traffic at the spoke airports will decrease (top figure); (b) whether traffic will remain the same at all the spoke airports (central figure); or (c) whether traffic will grow at all spoke airports (bottom figure). Clearly, traffic at the hub airport is expected to increase in each case. These possibilities show our uncertainty at this stage without having a suitable model of airline economics and airport pricing. Such a model would be useful in the context of an EIA to guide the consequences of airline operations under FC networks or HS networks.

From an economic point of view, the marginal cost of additional congestion and environmental damage to society should not exceed the marginal benefits of additional aircraft operations at the hub airport. In the short run, there are various regulatory approaches that could be adopted by airport management to ensure that the damage caused by extensive hubbing is not excessive and/or to fund environmental mitigation programs for those affected in the 'footprints of pollution' as indicated in Figure 2. First, there are fiscal measures such as an airport tax, which can be an aircraft/operation-related tax (based on noise certification category, carbon dioxide emission level, aircraft weight, time of the day, etc.) or a passenger-related tax (based on whether connecting or origin/destination traffic, time of the day, etc.). Second, regulatory authorities can adopt measures to reduce the externalities of extensive hubbing such as emission and noise limits, modified approach and departure procedures, quota on aircraft operations, airport passenger caps and night time curfews. Most of these measures are typically aimed at existing traffic levels. In the medium to long-term, a more challenging regulatory framework could induce changes in technology (e.g., the substitution of Stage 3 aircraft (or a more stringent version of Stage 3 aircraft) for the noisier Stage 2 aircraft), changes in fleet mix (smaller or larger aircraft) as well as changes in demand patterns. Because of the complexity of the problem, the approach adopted in this paper is a short-term analysis where it is assumed that airlines face a fixed level of technology. We also concentrate on an environmental levy imposed on airlines since: (a) it seems more appropriate in a short-run analysis; and (b) it is likely to be more straightforward to implement without recourse to time-and resource-consuming EIA and mitigation, such as a FAA Part 150 Noise Study.

An important analytical step is to assess short-term and long-term air service implications from the imposition of an environmental levy for excessive hubbing. If such charges were imposed as a tax on the aviation industry to fund 'environmental management' plans, it is not clear how airlines would respond[14]. An aircraft/operation-related tax and a passenger-related tax

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[13]The main objective of the FAA Part 150 Noise Study is to establish a national uniform airport noise compatibility program.

[14]Conceptually, the problem is one similar to assessing the impacts of peak-period pricing at airports (see,

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translates into a reduction of the number of flights and a fare increase, for reasons which will be outlined from the airline economic model presented in Section 3. In a more general framework and in the longer run, however, airlines could not only alter pricing and flight scheduling but are also likely to modify network design and fleet mix. The extent of these changes will depend on the nature of airline competition, in particular the market structure where airlines operate (monopoly versus oligopoly), the basic demand conditions (demand fare elasticity, elasticity of demand with respect to flight frequency, exogenous demand shift) and the technology available. The range of airlines' potential responses can be quite broad: (a) pass on the charges directly as an increase in fares; (b) reduce the number of flights to the hub airport without reducing the number of passengers carried by implementing operational and aircraft type changes; (c) pull out from the hub airport and/or modify the network; and (d) absorb extra costs and maintain existing routes, frequencies and aircraft type. The conceptual diagram presented in Figure 3 (see page 26) outlines the likely impacts following the imposition of any environmental levy. For the purpose of this paper, we consider the monopoly case, where the airline operates on a system of airports managed by a single airport authority. In this way, we avoid two potentially important issues: airline competition and competition between airports.

# 3 The Model

## 3.1 Assumptions

As discussed in the previous section, the aim of the model is to determine how a move from a FC network to a HS network affect the number of aircraft operations and the equivalent environmental impacts on communities around the system of airports. This issue is addressed by proposing a model of airline economics similar to Schmalensee (1977). However, three principal features differ in this paper. First, the model allows for an unregulated monopolist airline to set both prices and the number of flights. Second, the model explicitly takes the multi-market nature of airline operations into account. Third, the model allows for an endogenous determination of the optimal network. Hence, the airline's choice variables are the network configuration (FC versus HS), flight frequencies, and prices.

The following notation and assumptions will be adopted. It is assumed that a monopoly airline operates aircraft on the legs of a given network composed of three cities, $A, B$ and a potential hub city, $H$ (see Figure 1). Consequently, there are three city-pair markets $ij$ with $ij = AH, BH, AB$. Let $Q_{ij}$ represent the number of passengers travelling from city $i$ to city $j$ and back, plus the number of passengers travelling from city $j$ to city $i$ and back. Let $F_{ij}$ be the number of flights offered by the airline in market $ij$, and let $K_{ij}$ be the capital stock it employs to transport passengers on market $ij$. As suggested by Schmalensee (1977), treating technology (aircraft types and seating configurations) as exogenous in the short run, $F_{ij}$ and $K_{ij}$ are assumed proportional, i.e., $K_{ij} = F_{ij}/u$, where $u$ is a positive constant which can be interpreted as the number of flights per aircraft per time unit (day, week, year). Because of the existence of an active and competitive rental market for aircraft (capital stock), it is assumed that the cost of changing the $K_{ij}$ (and therefore the $F_{ij}$) is negligible. Given the above notation, the load factor $L_{ij}$ on city-pair $ij$ is defined as $Q_{ij}/(\mu F_{ij})$, where $\mu$ is a positive (exogenous) constant, measuring the seating configuration[15] (available seats per flight).

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e.g., Barrett et al., 1994).

[15]The constraints that, in equilibrium, the $L_{ij} \leq 1$ are assumed nonbinding in the subsequent analysis. Additionally, the requirement that the $F_{ij}$ be integers is omitted.

The cost function is assumed to be linear and separable in $F_{ij}$ and $Q_{ij}$ for each market $ij$. Following Schmalensee (1977), let us assume that the total cost function is given by

$$TC = \sum_{ij} f(Q_{ij}, K_{ij}) = \sum_{ij} tQ_{ij} + (r + su)K_{ij} \equiv \sum_{ij} tQ_{ij} + bF_{ij}, \qquad (1)$$

where $t$ is the cost incurred by the airline in transporting a passenger and $b \equiv [(r + su)/u]$ is the cost involved in offering a flight to a city-pair market. Flight cost $bF_{ij}$ is the sum of capital cost of capacity, $rK_{ij}$, and operating cost of flights, $sF_{ij}$. For simplicity, depreciation is neglected so that $r$ reflects the cost of capital funds, e.g., the service of the debt, and passenger-related capital costs are assumed insignificant. Fuel costs, pilot wages, and airport fees are the main components of the operating costs $s$. Notice that the cost specification in (1) does not allow for cost-based linkages across markets (costs complementarities or costs substitutabilities). While economies of scope and economies of density are potentially important in airline economics (see, *inter alia*, Caves *et al.*, 1984, Brueckner and Spiller, 1994), they would considerably complicate the analysis presented in this paper[16]. For computational convenience and exposition of principles, we also assume that the monopolist airline operates in a symmetric network where aircraft fly on legs of the same distance (as indicated in Figure 1 and Figure 2).

Following previous authors (see, e.g., Douglas and Miller, 1974, De Vany, 1975, and Schmalensee, 1977), we suppose that the demand $Q_{ij}$ for a return journey in any given city-pair market $ij$ is influenced by the level of fares $P_{ij}$ and a quality-of-service related variable, the number of flights offered in the market $F_{ij}$. This assumes that travellers are able to place a dollar value on a non-price service attribute measured by the level of frequency. The latter occurs since higher flight frequencies are associated with lower frequency delay costs and higher utility, all else equal (see Douglas and Miller, 1974). In order to derive useful results, let us assume that the demand function for a return journey in any given city-pair market $ij$ is given by

$$Q_{ij} = Z_{ij} P_{ij}^{-\epsilon} F_{ij}^{\alpha}, \qquad \forall\ ij = AH, BH, AB \qquad (2)$$

where $Z_{ij}$ is a market-specific demand shift parameter. It is readily verified that the demand function is increasing and strictly concave in $F_{ij}$ when $0 < \alpha < 1$, and decreasing in $P_{ij}$ for all $\epsilon > 0$. Notice that the specification in (2) is a special case of Schmalensee (1977). This specification has found strong empirical support. In particular, estimates of the elasticity of demand with respect to flight frequency $\alpha$ are provided by several studies. Scholars generally admit that the latter elasticity is less than one[17]. Notice that the demand specification (2) assumes a constant demand fare elasticity equal to $\epsilon$ (in absolute value). Most empirical studies in airline transport economics exhibit a demand fare elasticity greater than one[18] (in absolute value). In fact, in the present problem, existence and uniqueness of the equilibrium require that $\alpha < 1$, and $\epsilon > 1$. Throughout the paper it is assumed that the latter conditions are met.

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[16]See also our discussion in Section 3.3.

[17]De Vany (1975) and Panzar (1979) found values for $\alpha$ near one and around 0.4, respectively. Still using data on the U.S.A. domestic market, Morrison and Winston (1986) found elasticity frequencies around 0.2 for business travellers and around 0.05 for leisure traffic. Recently, using mainly data on intra-European markets, Berechman and de Wit's (1996) results suggest a demand elasticity frequency of 0.7 for business travel and 0.3 for tourist travel.

[18]It is generally admitted that price elasticities mainly depend on the trip purpose and the distance. Oum *et al.*, 1993, suggest demand price elasticities of 1.1 for business travel and 1.5 for tourist travel, indicating that the latter is more price elastic than the former. Using data for Australia, Mitchell McCotter (1994a) reports price elasticities for international markets to and from Australia to vary from 0.5 to 2.0, while the price elasticities vary from 0.5 to 2.3 and from 0.5 to 1.5 for interstate domestic routes and regional routes, respectively.

## 3.2 The Fully-Connected (FC) Network

Under the FC network of Figure 1, the monopolist airline operates aircraft on all the legs $l$, $l = 1, 2, 3$, of the network. The airline's choice variables are its $P_{ij}$ and $K_{ij}$ (or equivalently, $F_{ij}$) for each market $ij = AH, BH, AB$. Its profit function is

$$\Pi^{FC} = \sum_{ij} (P_{ij} - t)Q_{ij} - (r + su)K_{ij}. \qquad ij = AH, BH, AB \qquad (3)$$

Optimal values for $P_{ij}$ and $K_{ij}$ are the solutions of the following system of first order conditions:

$$\frac{\partial \Pi^{FC}}{\partial P_{ij}} = Q_{ij}(\cdot) + (P_{ij} - t)\frac{\partial Q_{ij}(\cdot)}{\partial P_{ij}} = 0, \qquad \forall\, ij = AH, BH, AB \qquad (4)$$

$$\frac{\partial \Pi^{FC}}{\partial K_{ij}} = (P_{ij} - t)\frac{\partial Q_{ij}(\cdot)}{\partial K_{ij}} - (r + su) = 0. \qquad \forall\, ij = AH, BH, AB \qquad (5)$$

Equations (4) state that in the monopoly equilibrium, marginal revenue of output equals marginal passenger cost $t$, for each market $ij$. The second set of first order conditions, equations (5), state that the airline increases its stock of capital (or the number of flights) as long as the additional net revenue from this increase exceeds the additional costs, for each market $ij$. Using equation (2), it can be verified that optimal values for $P_{ij}$ and $K_{ij}$, denoted by $P_{ij}^{FC}$ and $K_{ij}^{FC}$, are

$$P_{ij}^{FC} = \epsilon t/(\epsilon - 1), \qquad \forall\, ij = AH, BH, AB \qquad (6)$$

and

$$K_{ij}^{FC} = \frac{1}{u}F_{ij}^{FC} = \frac{1}{u}\Big[\frac{b}{\alpha Z_{ij} P_{ij}^{-\epsilon}(P_{ij} - t)}\Big]^{\frac{1}{\alpha - 1}}, \qquad \forall\, ij = AH, BH, AB \qquad (7)$$

respectively. Using equations (6), we have that the price cost margin of a passenger, $(P_{ij}^{FC} - t)$, is equal to $t/(\epsilon - 1) > 0$, $\forall\, \epsilon > 1$, which is decreasing as the demand fare elasticity increases. Assuming that the latter condition is always satisfied under the monopoly equilibrium, it can be easily shown that $F_{ij}^{FC} > 0$. Under a symmetric network, let us focus on a symmetric equilibrium where $Z_{ij} = Z$, $\forall\, ij$. Consequently, we have that $P_{ij}^{FC} = P^{FC}$ and $K_{ij}^{FC} = K^{FC}$, $\forall\, ij$. Given (6), the reduced form of the optimal frequencies and the reduced form of the profit function[19] can be written as

$$F^{FC} = \Big[\frac{b(\epsilon - 1)}{\alpha Z t(\frac{\epsilon t}{\epsilon - 1})^{-\epsilon}}\Big]^{\frac{1}{\alpha - 1}}, \qquad (8)$$

and

$$\Pi^{FC} = 3b[\frac{1 - \alpha}{\alpha}]\Big[\frac{b(\epsilon - 1)}{\alpha Z t(\frac{\epsilon t}{\epsilon - 1})^{-\epsilon}}\Big]^{\frac{1}{\alpha - 1}} \equiv 3b[\frac{1 - \alpha}{\alpha}]F^{FC}, \qquad (9)$$

respectively. Since

$$\frac{\partial F^{FC}}{\partial Z} = \frac{1}{1 - \alpha}\frac{1}{Z}F^{FC} > 0, \qquad \forall\, \alpha < 1 \qquad (10)$$

we have that both the number of frequencies and profit increase after an exogenous shift in demand $Z$. Given our discussion in Section 2, the result of equation (10) suggests that an exogenous growth in demand for air transport services throughout the network induces an increase of the number of aircraft operations at each airport and, as a result, a proportional

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[19]The symmetric structure reduces the monopolist problem to a two variables problem. It can be easily verified that, in equilibrium, the Hessian matrix of the second order conditions is negative semidefinite.

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increase in the 'footprints of pollution' of Figure 1 (that is, larger dotted circles around each node). Finally, using equations (2), (6) and (7), in equilibrium the load factor for any city-pair market is

$$L^{FC} = \frac{Q^{FC}}{\mu F^{FC}} = \frac{(\epsilon - 1)b}{\mu \alpha t} \leq 1, \tag{11}$$

where $Q^{FC}$ corresponds to the optimal number of passengers carried on any (symmetric) market of the FC network configuration.

## 3.3 The Hub-and-Spoke (HS) Network

As suggested by Figure 2, let us assume that under a hubbing structure the monopolist airline operates aircraft[20] on the legs $l$, $l = 1, 2$, of the network. Consequently, the $AB$ market is indirectly served via a connecting flight at the hub airport $H$. Notice that since entry is ruled out in this monopoly model, the incumbent airline does not necessarily lose all of its customers on the $AB$ market. For the purpose of this paper, it is assumed that the airline captures at least a fraction $0 \leq \lambda < 1$ of the $AB$ market as connecting passengers who route through leg 1 and leg 2. In reality, those connecting passengers are more likely to be business oriented travellers than tourist oriented travellers, since the former have a higher value of time and lower price elasticity. Since our model presumes homogenous travellers, we shall assume that there is a positive fraction of connecting travellers willing to be routed through the hub. Given the above assumption, the profit function under the HS network structure can be expressed as

$$\Pi^{HS} = \sum_l (P_L - t)Q_l - (r + su)K_l, \qquad l = 1, 2 \tag{12}$$

where

$$Q_l = (1 + \lambda)ZP_l^{-\epsilon}F_l^{\alpha}, \qquad l = 1, 2 \tag{13}$$

can be interpreted as the total passenger demand on leg $l$. For example, on leg 1 the monopolist airline will transport all the $AH$ passengers plus the fraction $\lambda$ of $AB$ passengers. Similarly, $P_l$ and $F_l$ can be interpreted as the price for being transported on leg $l$ and the number of flights provided on leg $l$, respectively. In order to derive useful comparisons with the FC configuration, we assume an identical symmetric demand shift parameter $Z$.

At this stage of the analysis, the following two remarks are in order. First, the above formulation implicitly assumes that the fraction $\lambda$ of connecting passengers are charged twice the price per leg. The latter arises because these passengers are now transported on two legs of the journey, using two different flights. Because the direct (nonstop) $AB$ service is unavailable, passengers have no choice but to pay the premium and incur extra travel time once they decide to travel[21]. Although the basic travel time increases under the HS configuration (increase in distance and layover time) a significant increase in flight frequency in leg 1 and leg 2 can substantially reduce the frequency delay in the $AB$ market. Second, implicit to the formulation of the profit equation (12) is the idea that the HS network is not more costly to operate[22]. Some authors (see, e.g., Levine, 1987, Butler and Huston, 1989) argue that hubbing

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[20]Aircraft types and seating configurations are assumed to be identical to the FC case.

[21]When economies of traffic density arise, the connecting travellers contribute to reducing the marginal cost of the leg which, all else equal, induces the airline to set lower fares. In this latter case, one would expect the connecting travellers to pay less than twice the price per leg (see, e.g., Brueckner and Spiller, 1991, and Hendricks et al., 1995).

[22]In fact productive efficiencies are expected to arise under HS networking, especially when economies of density are strong.

operations are associated with sunk investment costs. Others also suggest that airlines incur additional fixed costs by routing flights between two spoke cities through the hub (see, e.g., Oum *et al.*, 1995). While most of the comparative static results derived in this paper are not affected by fixed costs, we are aware that the magnitude of these fixed costs can play a role in some of our results. For the sake of simplicity, we assume that these costs are negligible. The latter assumption is more likely to hold when airports face a low level of congestion and/or are not slot-constrained, and when these costs are incurred by municipalities or local governments airport owners rather than airlines[23].

Following the same approach presented in the previous section, optimal values for $P_l$ and $K_l$ are the solutions of the following system of first order conditions:

$$\frac{\partial \Pi^{HS}}{\partial P_l} = Q_l(\cdot) + (P_l - t)\frac{\partial Q_l(\cdot)}{\partial P_l} = 0, \qquad \forall \, l = 1, 2 \tag{14}$$

$$\frac{\partial \Pi^{HS}}{\partial K_l} = (P_l - t)\frac{\partial Q_l(\cdot)}{\partial K_l} - (r + su) = 0. \qquad \forall \, l = 1, 2 \tag{15}$$

In equilibrium, we have that

$$P_l^{HS} = \epsilon t/(\epsilon - 1), \qquad \forall \, l = 1, 2 \tag{16}$$

and

$$K_l^{HS} = \frac{1}{u}F_l^{HS} = \frac{1}{u}\Big[\frac{b}{\alpha Z(1+\lambda)P_l^{-\epsilon}(P_l - t)}\Big]^{\frac{1}{\alpha-1}}. \qquad \forall \, l = 1, 2 \tag{17}$$

Economic intuition requires that the number of optimal flights increases as the fraction of connecting travellers $\lambda$ increases. Indeed, using equation (17) we can easily show that

$$\frac{\partial F_l^{HS}}{\partial(1+\lambda)} = \frac{1}{1-\alpha}\frac{1}{1+\lambda}F_l^{HS} > 0. \qquad \forall \, \alpha < 1$$

Under a symmetric network, it must be the case that $P_l^{HS} = P^{HS}$ and $K_l^{HS} = K^{HS}$, $\forall \, l$. Given equations (16), the reduced forms of flight frequencies and profit can be expressed as

$$F^{HS} = \Big[\frac{b(\epsilon - 1)}{\alpha Z(1+\lambda)t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\Big]^{\frac{1}{\alpha-1}}, \tag{18}$$

and

$$\Pi^{HS} = 2b[\frac{1-\alpha}{\alpha}]\Big[\frac{b(\epsilon - 1)}{\alpha Z(1+\lambda)t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\Big]^{\frac{1}{\alpha-1}} \equiv 2b[\frac{1-\alpha}{\alpha}]F^{HS}, \tag{19}$$

respectively. Given equation (18), it is straightforward to show that both the number of frequencies and profit increase after an exogenous shift in demand $Z$. As the 'footprints of pollution' are a function of the number of aircraft movements, a proportional growth in demand amounts to an increase in externalities at each airport, all else being equal. Finally, using equations (13), (16) and (17) we have that, in equilibrium, the load factor on any leg operated in the HS network is

$$L^{HS} = \frac{Q^{HS}}{\mu F^{HS}} = \frac{(\epsilon - 1)b}{\mu \alpha t}, \tag{20}$$

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[23] For example, because of the potential economic benefits flowing from hubs, several local authorities in the U.S.A. have taken steps to support their incumbent hub airline in the form of public investment in airports and expenditure on various inducements to airlines, such as tax breaks, low-cost loans and subsidies (see Hanlon, 1996).

where $Q^{HS}$ corresponds to the optimal number of passengers carried on any leg of the HS network. From the comparison of expressions (11) and (20) we notice that the load factor is constant under both network configurations. The latter result is not surprising. Because of the assumptions of the model -namely, that the stock of capital can be easily adjusted (for a given technology) and that the number of flights can be treated as a continuous variable - the number of flights is proportional to the quantity of travellers at a given (constant) load factor. In other words, if demand increases it is assumed that the airline will provide more flights, all else equal[24].

## 3.4 Comparison of the Results

Given the results obtained in Section 3.2 and Section 3.3, we are now able to state the following propositions.

**Proposition 1** *Given the assumptions of the model, it is optimal for the monopolist airline to operate a HS network when* $\lambda \geq [\frac{3}{2}]^{1-\alpha} - 1$. *(See Proof in Appendix).*

Proposition 1 states the condition under which it is optimal for the airline to operate a HS network. What is the economic intuition of Proposition 1 ? Operating a HS network is a dominant strategy if the profit associated with the HS configuration is larger than the profit associated with the FC network. This is more likely to arise when the fraction of connecting passengers is large and/or when the elasticity of demand with respect to flight frequency is important. Indeed, as the elasticity of demand with respect to flight frequency tends to unity, the above condition requires that $\lambda \geq 0$. Similarly, as $\alpha$ tends to 0, the condition is met when $\lambda \geq 1/2$. In other words, the greater the elasticity of demand with respect to flight frequency, the lower $\lambda$ required for $\Pi^{HS} \geq \Pi^{FC}$. When such an elasticity is very large, -that is, close to unity - then any $\lambda \geq 0$ is compatible with the choice of a HS network structure.

**Proposition 2** *In equilibrium, we have that under the FC network structure, the number of flights operated at each airport (i.e., total aircraft movements), $A, B$ and $H$ correspond to $2F^{FC}$. Under the HS network structure, the number of flights operated at the spoke airports $A$ and $B$ is equal to $F^{HS}$, while the number of flights operated at the hub airport $H$ is equal to $2F^{HS}$. Consequently, we have the following results:*

1. *The number of flights operated at the spoke airports $A$ and $B$ is larger under the FC structure when $\lambda < 2^{1-\alpha} - 1$, and*

2. *The number of flights operated at $H$ is greater under the HS network structure for any $\lambda > 0$. (See Proof in Appendix).*

The first part of Proposition 2 states that when the elasticity of demand with respect to flight frequency is high, the number of flights operated at the spoke airports $A$ and $B$ under the FC network structure is greater than under the HS configuration, whenever $\lambda$ is sufficiently small. For example, $2F^{FC} > F^{HS}$ is compatible with $\alpha = 0.9$, whenever $\lambda < 0.071$. On the other hand, when $\alpha$ tends to 0, -that is, passengers are not sensitive to flight frequency - we have that $2F^{FC}$ is always greater than $F^{HS}$, since $\lambda$ cannot exceed one. Put differently, the lower the elasticity of demand with respect to flight frequency, the more likely the number

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[24]In reality, because of capital indivisibilities, airlines adjust both the load factor and the number of flights following a shift in demand.

of flights operated at $A$ and $B$ is greater under the FC network structure. However, it is important to stress that, for a sufficiently large $\lambda$, Proposition 2 implies that the number of flights at the spoke airports can be actually larger under the HS structure, although the direct $AB$ service has been dropped. In terms of environmental impacts the result of the first part of Proposition 2 is striking. It suggests that when the inequality $\lambda < 2^{1-\alpha} - 1$ is binding, a reduction of the aircraft operations at the spoke airports is likely to imply an equivalent decline in the 'footprints of pollution', as shown in Figure 2 (a). When $\lambda > 2^{1-\alpha} - 1$ the number of movements at the spoke airports are larger than under the FC network, so that the 'footprints of pollution' are actually larger under the HS configuration, as shown in Figure 2 (c).

The second part of Proposition 2 shows that as soon as the airline captures some connecting travellers, i.e., $\lambda > 0$, the number of flights operated at the hub airport is greater under a HS network configuration. Clearly, the latter result is not surprising. Under the HS configuration, airport H becomes the central node of the network, and all else equal, it attracts at least the same amount of traffic (aircraft operations) as under the FC configuration. In terms of environmental impact, the latter result clearly suggests that, when $\lambda > 0$, the 'footprints of pollution' are always larger at the hub airport under the HS configuration, as shown in Figure 2.

The theoretical results presented in Proposition 2 suggest that different patterns of flight movements arise at airports, according to the configuration of the network operated by the airline. Such results are in accordance with empirical evidence on the aftermath of the U.S.A. airline deregulation (1978), which has been characterized by airlines shifting from a FC network to a HS network (see, e.g., Kanafani and Ghobrial (1985), Borenstein (1992)). Several studies report that the adoption of the HS structure greatly explains the significant reduction in aircraft movements at small hubs and nonhubs airports, while at the same time the number of weekly departures at large hubs has increased[25] (see, *inter alia* Graham *et al.*, 1983, GAO, 1996). Clearly, in a dynamic perspective, factors like demand growth, technological changes, fuel cost, environmental concerns, regulatory regime, etc., are likely to influence the level of frequency of service at the network level. Our main point in Proposition 2 is to show that, all else equal, the number of operations at the various airports and the equivalent environmental impacts depend on the number of connecting travellers in the overall network.

**Proposition 3** *Assume that it is optimal for the monopolist airline to operate a HS network, i.e., that $\lambda \geq [\frac{3}{2}]^{1-\alpha} - 1$ (see Proposition 1). In equilibrium, we have that the HS configuration provides a higher net social welfare (W) throughout the network, i.e., $W^{HS} > W^{FC}$. (See Proof in Appendix).*

Proposition 3 suggests that when the fraction of connecting travellers $\lambda$ is such that it is profitable to operate a HS network configuration then the net social welfare throughout the network is also maximized under the HS configuration. Although the $AB$ direct service has been cancelled, and although those connecting travellers are charged an additional amount of money to fly through the hub, it turns out that the consumers' surplus throughout the network is larger under the HS structure because total travellers attach a positive value to the increase in flight frequencies associated with the HS configuration. The result of Proposition 3 indicates that, under certain conditions, hubbing can be valuable for both the airline and travellers[26].

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[25] See Morrison and Winston (1986) and Butler and Huston (1990) for a somewhat challenging view.

[26] Under increasing returns to traffic density, HS networking would be further welfare improving since it would allow for a better exploitation of productive efficiencies.

To summarize, using a simple analytical model we have shown in this section: (a) under which condition it is optimal for the airline to operate a HS network; (b) the optimal fares and number of flights that maximize its profit given the configuration chosen in the first stage; and (c) that the choice of the HS network configuration is compatible with social welfare maximization for the entire network. The central result is that the (rational) decision to operate a HS network affects the pattern of aircraft movements at the different airports of the network which, in turn, affects the environmental impacts. In the remainder of this paper, we assume that the result of Proposition 1 holds such that it is optimal for the monopolist airline to operate a HS network. In other words, we assume that the parameters $\alpha$ and $\lambda$ vary within the range defined by the first row of Table 2 (see page 2). It is apparent from our analysis that the monopolist airline does not fully internalize the costs associated with the development of the hub airport since such externalities are not reflected in the airline choice variables. A general equilibrium analysis would, for example, include such externalities incurred by the non-travelling population living in proximity of the hub airport. In Section 4 we address some of these issues, by assuming that the airport authority constrains the airline to internalize some of the costs associated with these externalities through an additional tax.

## 4 The Effects of Changes in Airport Pricing Policy: A Comparative Static Analysis

The aim of this section is to investigate some comparative static properties of this model. To be more specific, we are interested in how endogenous variables are affected by a change in key exogenous variables, such as the operating costs of a flight or the cost of transporting a traveller. As raised in Section 2, because (negative) externalities associated with HS operations are not fully reflected in the airline's choice variables, it is assumed that the government enacts legislation so that the airport authority[27] constrains the airline to internalize some of these costs through an additional (exogenous) tax. We assume that the airport authority in addressing airport externalities uses two levy options: a tax per passenger; and a tax per aircraft movement. Both taxes are incurred by the airline such that the use of either instrument induces an increase in its total costs. On the one hand, an additional tax per traveller results in an increase of $t$, the cost incurred by the airline in transporting an individual passenger. On the other hand, an additional tax per flight results in higher operating costs of flights $s$, all else equal.

The basic question that we want to investigate can be stated as follows: to what extent can the airport authority affect resource allocation (flight movement), given that the basic parameters $\alpha$ and $\lambda$ are such that it is optimal for the airline to operate the HS configuration ? In other words, if hubbing has some economic value for the airline and the travelling public, how much revenue can be extracted from the airline for environmental mitigation so that the airline still chooses to operate a HS network ? Alternatively, if airport management wants to reduce the number of flights at the hub airport, say, to the number of flight which prevails under the FC configuration (e.g., a movement cap to maintain the base-year level of noise impacts), what optimal tax should be charged ?

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[27]Throughout this section it is implicitly assumed that a single airport authority is in charge of the three airports in order to avoid conflicting interests at the network level. Notice that this is the case of major airports in Australia operated by the FAC.

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## First Scenario: An Aircraft-Operation-Related Tax

A change in the operating costs of a flight $s$ will affect both the number of flights and profit of the HS airline. Indeed, given equation (18), and noting that $b \equiv [(r + su)/u]$, we have that

$$\frac{\partial F^{HS}}{\partial s} = \frac{1}{\alpha - 1} \frac{1}{b} F^{HS} < 0, \quad \text{since} \quad \alpha < 1. \tag{21}$$

In accordance with intuition, in equilibrium, as the operating costs of a flight increase the airline reduces the number of flights. Given expression (19), and the result obtained in equation (21), we have that

$$\frac{\partial \Pi^{HS}}{\partial s} = 2 \frac{1 - \alpha}{\alpha} \left[ F^{HS} + b \frac{\partial F^{HS}}{\partial s} \right] = -2 F^{HS} < 0. \tag{22}$$

The latter result shows that an increase in the costs of operating an aircraft reduces profit. Using equation (22), the change in the value of $\Pi^{HS}$ which would result from a change in the value of $s$ may be estimated as $d\Pi^{HS} = -2F^{HS}ds$. If the airport authority wants to reduce the profit by the difference between $\Pi^{HS} - \Pi^{FC} \equiv d\Pi > 0$, then the optimal increase in the operating costs can be approximated[28] by $ds^{\pi} \approx \frac{-d\Pi}{-2F^{HS}}$ or using equations (9) and (19),

$$ds^{\pi} \approx \frac{\frac{b(1-\alpha)}{\alpha} \left[ 2 - 3(1+\lambda)^{\frac{1}{\alpha-1}} \right] F^{HS}}{2 F^{HS}},$$

$$\approx \frac{b(1-\alpha)}{2\alpha} \left[ 2 - 3(1+\lambda)^{\frac{1}{\alpha-1}} \right] > 0. \tag{23}$$

Similarly, if the airport authority wants to reduce the number of flights at the hub airport, say, to the number of flights operated under the FC structure, i.e., by the difference between $2F^{HS} - 2F^{FC} \equiv dF > 0$, then using equations (8), (18), and (21), we have

$$ds^{f} \approx \frac{-dF}{\frac{1}{\alpha-1} \frac{1}{b} F^{HS}} = \frac{\left[ 1 - (1+\lambda)^{\frac{1}{\alpha-1}} \right] F^{HS}}{\frac{1}{1-\alpha} \frac{1}{b} F^{HS}},$$

$$\approx (1 - \alpha) b \left[ 1 - (1 + \lambda)^{\frac{1}{\alpha-1}} \right] > 0. \tag{24}$$

Equations (23) and (24) suggest that the optimal taxes, $ds^{\pi}$ or $ds^{f}$, are independent[29] of both the demand price elasticity $\epsilon$ and the cost of transporting a traveller $t$. Furthermore, for a given $\alpha$, both expressions (23) and (24) are increasing in $\lambda$. In other words, as the fraction of connecting travellers increases, the optimal tax which would induce a reduction of profit or a reduction of the number of flights at the hub airport increases. The more connecting passengers, the greater number of flights, the larger the profit and the larger the tax, ceteris paribus !

Using a numerical example, it can be verified that when $\epsilon = 1.5, \alpha = 0.4, Z = 1000, r = 10, u = 5, t = 2, s = 50$, we have that $b = 52, P = 6$, and $(ds^{\pi}, ds^{f}) = (2.44; 11.05)$ for $\lambda = 0.3$, and $(ds^{\pi}, ds^{f}) = (7.05; 12.28)$ for $\lambda = 0.35$. Put differently, if the airport authority wants to reduce the profit by $d\Pi$, and the initial operating costs of a flight are $s = 50$, the additional tax would be equal to 2.44 (i.e., an increase of 4.88%), and 7.05 (i.e., an increase of 14.1%) for $\lambda$ equal to 0.3 and 0.35, respectively. Also, note that from the latter example, the optimal tax

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[28]The smaller the difference $d\Pi$, the better the approximation.

[29]This result follows from the functional form for the demand function.

required to reduce the number of flights by $dF$ is greater than the tax which would reduce the profit by $d\Pi$, i.e., $ds^f > ds^\pi$. While this result is due to the choice of the parameter values, it also suggests that a policy aiming at a reduction in the number of flights operated at the hub airport could induce the airline to refrain from operating a HS network, and to favour the FC configuration, if the latter would secure higher profits. Finally, it can be observed that both $ds^\pi$ and $ds^f$ are linear in $s$ (since $b$ is linear in $s$). Therefore, given $\alpha$ and $\lambda$, $ds^\pi$ and $ds^f$ are proportional to the operating costs of a flight.

### Second Scenario: A Passenger-Related Tax

Contrary to the previous case, a change in the basic cost of transporting a passenger $t$ will affect fares as well as the number of flights and profit of the airline. Using expression (18), we have that

$$\frac{\partial F^{\text{HS}}}{\partial t} = \frac{\epsilon - 1}{\alpha - 1} \frac{1}{t} F^{\text{HS}} < 0, \quad \text{since} \quad \alpha < 1 \quad \text{and} \quad \epsilon > 1. \tag{25}$$

Not surprisingly, as $t$ increases prices increase and demand decreases, so that the airline reduces flight frequencies. Given expression (19) and equation (25) we can write

$$\frac{\partial \Pi^{\text{HS}}}{\partial t} = 2b \frac{1-\alpha}{\alpha} \left[ \frac{\partial F^{\text{HS}}}{\partial t} \right] = -2b \frac{\epsilon - 1}{\alpha\, t} F^{\text{HS}} < 0. \tag{26}$$

Therefore, an increase in $t$ generates a reduction in the airline's profit, all else being equal. The change in the value of $\Pi^{\text{HS}}$ which would result from a change in the value of $t$ can be estimated as $d\Pi^{\text{HS}} = [-2b(\epsilon - 1)(\alpha\, t)^{-1} F^{\text{HS}}]dt$. As for the previous scenario, if the airport authority wants to reduce the profit by $d\Pi > 0$, then the optimal increase in $t$ can be approximated by

$$dt^\pi \approx \frac{-d\Pi}{-2b \frac{\epsilon-1}{\alpha\, t} F^{\text{HS}}},$$

or using equations (9) and (19),

$$dt^\pi \approx \frac{(1-\alpha)\, t \left[ 2 - 3(1+\lambda)^{\frac{1}{\alpha-1}} \right]}{2(\epsilon - 1)} > 0. \tag{27}$$

Finally, a reduction of the number of flights at the hub airport by $dF$, can be obtained through an increase of $t$ equal to

$$dt^f \approx \frac{-dF}{\frac{\epsilon-1}{\alpha-1} \frac{1}{t} F^{\text{HS}}},$$

or using equations (8) and (18),

$$dt^f \approx \frac{(1-\alpha)\, t \left[ 1 - (1+\lambda)^{\frac{1}{\alpha-1}} \right]}{(\epsilon - 1)} > 0. \tag{28}$$

Two remarks are in order. First, note that both equations (27) and (28) depend on the value of the demand fare elasticity $\epsilon$. Actually, using equation (16) it is immediate that, for a given $\alpha$ and $\lambda$, $dt^\pi$ and $dt^f$ are proportional to the price cost-margins $(P - t)$. Secondly, notice that both expressions (27) and (28) are increasing in the fraction of connecting passengers $\lambda$. Using the same parameter values as in the numerical example of the first scenario, we have that $(dt^\pi, dt^f) = (0.075; 0.85)$ for $\lambda = 0.3$, and $(dt^\pi, dt^f) = (0.217; 0.945)$ for $\lambda = 0.35$. Therefore,

if the airport authority wants to reduce the profit by $d\Pi$, and initially $t = 2$, the additional tax would be equal to 0.075 (i.e., an increase of 3.75%), and 0.217 (i.e., an increase of 10.8%) for $\lambda$ equal to 0.3 and 0.35, respectively. Finally, since optimal fares are a linear function of $t$, the monopolist airline will be able to pass along any additional tax $dt$ to travellers on top of existing fares.

Which instrument is more preferable depends on several factors. First, note that a tax affects both the monopolist airline and the airline customers. Since it is the latter who mainly receive the benefits of air transportation, it seems fair that airline customers also bear their share of the social costs associated with this mode of transportation. However, given the results of the model, the travelling public and the airline do not share the burden of the tax equally, so that there is a potential for a distributional issue of the tax. Indeed, a passenger-related charge $dt$ will adversely affect travellers through both higher fares and lower frequencies. Consequently, consumers' surplus is likely to be lower with a passenger-related charge. Second, notice that the informational requirement for policy implementation differs under both scenarios. The first scenario requires information on the total costs of a flight $b$. The second requires information on the price-cost margin. Third, as discussed in Section 2.2, in the long run, an aircraft-operation-related tax could provide a greater incentive to increase airline operational efficiency and aircraft type changes. Finally, at this stage of the analysis, the model does not indicate whether a tax which explicitly targets profits is more effective (in addressing the externalities) than a tax which targets the number of flights/movements. Clearly, the results of this section suggest that any levy equal to $ds^f$ or $dt^f$ will reduce the number of movements at the hub airport such that the 'footprints of pollution' in Figure 2 will contract towards the (base case) level of Figure 1.

# 5 Conclusion

Whereas the economic impact of airline hubbing has been assessed in the literature, we argue that the environmental externalities due to extensive hubbing have not received sufficient attention. Aircraft arrivals and departures and passengers through hub airports have increased since airline deregulation in the U.S.A., and a similar phenomenon is likely to occur worldwide as the airline industry experiences more liberalization. Increased operations broadly bring three categories of environmental impacts: aircraft noise and ground running noise; aircraft emissions from landing, taxiing and take-off; and more ground access traffic which affect airport communities through greater annoyance and reduced amenity. All impacts culminate in a loss of property values. The principal contribution of this paper has been to focus explicitly on environmental externalities associated with extensive hubbing. Also many of the issues raised about hub airports are relevant for all types of airports experiencing growth in traffic, we argue in this paper that the problem of externalities is exacerbated by hub development. The absence of straightforward market solutions with respect to hubbing-related externalities has important consequences: externalities are not included in the hubbing airlines own cost calculations and are not fully reflected in their choice variables such as the network configuration, fares and frequencies.

When developments are being planned at the airport node to expand runway or terminal to accommodate growth in both air transportation supply (arising, e.g., from hub development) and demand, the practical challenge at the EIA stage is to formulate appropriate aircraft movements and demand forecasts and to examine the consequences of changes in environmen-

tal performance indicators on the environs. The latter is discussed in Section 2 where we present a conceptual spatial model which addresses the environmental impacts related to hub airport development. The spatial representation of FC and HS networks, with their associated 'footprints of pollution' around each airport node, suggests that a precise airline economic model is needed in order to assess the environmental impacts associated with airline network operations. The conceptual model strengthens the need for the different airport authorities to consider a system of airports as part of an integrated strategy, given the substitutability and/or complementarity relationship arising in an airline network.

In Section 3, we formally address the conceptual problem by proposing a model of airline economics. Schmalensee's (1977) model has been adapted by: (a) allowing the airline to set both prices and the number of flights; (b) accounting for the multi-market nature of airline operations; and (c) allowing for an endogenous determination of the optimal network. The FC network and the HS network in terms of the airline's choice variables have been contrasted in Section 3.4. The results of the model suggest that under sufficient connecting traffic, it is optimal for the monopolist airline to operate a HS network. We show that when the HS configuration is adopted, there is an increase in the number of flights operated at the hub airport and a potential reduction of flights operated at the spoke airports. The environmental impact implications of these results are discussed in the light of the conceptual model presented in Section 2. The paper also discusses the social welfare implications of these results. The comparative static properties of the model are investigated in Section 4 where we examine how endogenous variables are affected by a change in key exogenous variables, such as the operating costs of a flight or the cost of transporting a traveller. We assume that the airport authority considers externalities by imposing one of two policy instruments: a tax per passenger; and a tax per aircraft movement. When the airline operates a HS network, we show the optimal amount of tax which ensures a reduction in the number of aircraft operations at the hub airport.

The basic theoretical model could be extended in several ways. One would, for example, relax the constant price elasticity assumption and/or allow the load factor to be endogenous. The basic model could be extended to allow for city-pair market asymmetries (different population distribution) in the network. Clearly, further empirical research is necessary on airport systems to determine the direction and magnitude of changes (in terms of both aircraft movements and environmental impact) implicit on Figure 1 and Figure 2 following a hub development. Future research agenda on airline economics and airport hubbing would ideally include the development of a comprehensive environmental cost index at hub airports (so that an objective basis to calculate a levy could be provided), as well as an empirical assessment of the effects of a 'polluter pays' tax after such a tax has been introduced.

## Acknowledgements

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# Appendix

## Proof of Proposition 1

The proof follows from the comparison of the profit expressions (9) and (19). In equilibrium, we have that

$$\Pi^{HS} \geq \Pi^{FC} \iff 2b\Big[\frac{1-\alpha}{\alpha}\Big]F^{HS} \geq 3b\Big[\frac{1-\alpha}{\alpha}\Big]F^{FC},$$

$$\iff \Big[\frac{b(\epsilon-1)}{\alpha Z(1+\lambda)t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\Big]^{\frac{1}{\alpha-1}} \geq \frac{3}{2}\Big[\frac{b(\epsilon-1)}{\alpha Zt(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\Big]^{\frac{1}{\alpha-1}},$$

$$\iff (1+\lambda)^{\frac{1}{1-\alpha}} \geq \frac{3}{2},$$

$$\iff \lambda \geq \Big[\frac{3}{2}\Big]^{1-\alpha} - 1. \quad Q.E.D.$$

## Proof of Proposition 2

The proof follows from the comparison of the flight frequency expressions (8) and (18). In equilibrium, we have that

$$2F^{FC} > F^{HS} \iff 2\left[\frac{b(\epsilon-1)}{\alpha Z t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\right]^{\frac{1}{\alpha-1}} > \left[\frac{b(\epsilon-1)}{\alpha Z(1+\lambda)t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\right]^{\frac{1}{\alpha-1}}, \quad \text{for airports A and B}$$

$$\iff 2 > (1+\lambda)^{\frac{1}{1-\alpha}},$$

$$\iff \lambda < 2^{1-\alpha} - 1. \quad Q.E.D.$$

$$2F^{HS} > 2F^{FC} \iff 2\left[\frac{b(\epsilon-1)}{\alpha Z(1+\lambda)t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\right]^{\frac{1}{\alpha-1}} > 2\left[\frac{b(\epsilon-1)}{\alpha Z t(\frac{\epsilon t}{\epsilon-1})^{-\epsilon}}\right]^{\frac{1}{\alpha-1}}, \quad \text{for airport H}$$

$$\iff (1+\lambda)^{\frac{1}{1-\alpha}} > 1,$$

$$\iff \lambda > 0. \quad Q.E.D.$$

## Proof of Proposition 3

Net social welfare is defined as the sum of consumers' surplus $CS$ plus the economic profit of the monopolist. Given the assumptions of the model, we have that the consumers' surplus under the HS configuration is

$$CS^{HS} = 2\left[\int_{P^{HS}}^{\infty}\left[\int_{0}^{F^{HS}}(1+\lambda)ZP^{-\epsilon}F^{\alpha}\,dF\right]dP\right],$$

$$= \frac{2Z(1+\lambda)}{1+\alpha}\left(\frac{b}{(1+\lambda)Z\alpha}\right)^{\frac{1+\alpha}{\alpha-1}}\left[\int_{P^{HS}}^{\infty}P^{-\epsilon}\left(\frac{P^{\epsilon}}{P-t}\right)^{\frac{1+\alpha}{\alpha-1}}dP\right] > 0. \tag{29}$$

Similarly, the consumers' surplus under the FC configuration is

$$CS^{FC} = 3\left[\int_{P^{FC}}^{\infty}\left[\int_{0}^{F^{FC}}ZP^{-\epsilon}F^{\alpha}\,dF\right]dP\right],$$

$$= \frac{3Z}{1+\alpha}\left(\frac{b}{Z\alpha}\right)^{\frac{1+\alpha}{\alpha-1}}\left[\int_{P^{FC}}^{\infty}P^{-\epsilon}\left(\frac{P^{\epsilon}}{P-t}\right)^{\frac{1+\alpha}{\alpha-1}}dP\right] > 0. \tag{30}$$

Now, note that since $P^{FC} = P^{HS} = \frac{\epsilon t}{\epsilon-1}$, we have that

$$CS^{HS} - CS^{FC} = CS^{FC}\left[\underbrace{\frac{2}{3}(1+\lambda)^{\frac{2}{1-\alpha}} - 1}_{>0}\right] > 0.$$

The expression in square brackets has to be positive since we have assumed that $(1+\lambda) \geq \frac{3}{2}^{1-\alpha} \geq \frac{3}{2}^{(1-\alpha)/2}$. Therefore, since $\Pi^{HS} \geq \Pi^{FC}$ (by virtue of Proposition 1), and $CS^{HS} > CS^{FC}$, the latter unambiguously implies that $W^{HS} > W^{FC}$. Q.E.D.

Table 1: Hubbing and Airport Growth at the 30 Largest US Airports (1994)

| Airport | Percent Connecting Passengers | Enplanement Growth 1984-1994 | Departures Growth 1984-1994 | Rank by Size |
|---|---|---|---|---|
| Charlotte (CLT) | 77.0% | 107.5% | 65.1% | 13 |
| Pittsburgh (PIT) | 66.1% | 38.3% | 29.3% | 12 |
| Dallas (DFW) | 66.0% | 65.1% | 83.0% | 2 |
| Atlanta (ATL) | 63.3% | 28.6% | 17.8% | 3 |
| Cincinnati (CVG) | 62.8% | 191.2% | 79.3% | 28 |
| St. Louis (STL) | 58.3% | 34.3% | 52.6% | 10 |
| Memphis (MEM) | 56.9% | 50.5% | -1.1% | 26 |
| Chicago (ORD) | 56.1% | 49.3% | 49.7% | 1 |
| Denver (DEN) | 54.4% | 16.8% | 3.5% | 5 |
| Minneapolis (MSP) | 53.8% | 66.3% | 40.6% | 14 |
| Salt Lake City (SLC) | 52.4% | 115.9% | 47.7% | 25 |
| Houston (IAH) | 50.3% | 55.6% | 29.3% | 17 |
| Detroit (DTW) | 47.2% | 112.7% | 67.2% | 7 |
| Miami (MIA) | 35.2% | 29.1% | 3.9% | 6 |
| Phoenix (PHX) | 31.8% | 117.2% | 56.5% | 8 |
| New York-Kennedy (JFK) | 27.9% | -19.8% | -5.0% | 20 |
| San Francisco (SFO) | 27.8% | 23.0% | 1.1% | 11 |
| Philadelphia (PHL) | 25.7% | 64.7% | 56.2% | 19 |
| Seattle (SEA) | 22.9% | 93.0% | 90.9% | 21 |
| Los Angeles (LAX) | 22.8% | 27.6% | 21.3% | 4 |
| Honolulu (HNL) | 21.0% | 37.2% | 56.7% | 22 |
| Baltimore (BWI) | 19.9% | 94.0% | 38.8% | 27 |
| Newark (EWR) | 18.3% | 31.1 % | 10.2% | 9 |
| Orlando (MCO) | 17.1% | 109.9% | 40.8% | 24 |
| Las Vegas (LAS) | 15.7% | 144.0% | 77.0% | 18 |
| Boston (BOS) | 13.3% | 23.1% | 58.3% | 16 |
| Washington (DCA) | 11.1% | 5.0% | 2.0% | 23 |
| Tampa (TPA) | 11.0% | 41.0% | 8.1% | 30 |
| La Guardia (LGA) | 9.7% | 3.7% | 14.9% | 15 |
| San Diego (SAN) | 7.2% | 70.7% | 59.1% | 29 |

Source: USDOT Databank 1A, second quarter 1984 and 1994. Airport Activity Statistics of Certificated Route Air Carrier, USDOT, 1994.

Table 2: Matrix of Outcomes

| | $2F_{\rm FC} > F_{\rm HS}$ Case in Figure 2 (a) | $2F_{\rm FC} \leq F_{\rm HS}$ Case in Figure 2 (c) |
|---|---|---|
| $\Pi_{\rm HS} \geq \Pi_{\rm FC}$ | $\frac{3}{2} \leq (1+\lambda)^{\frac{1}{1-\alpha}} < 2$ | $(1+\lambda)^{\frac{1}{1-\alpha}} \geq 2$ |
| $\Pi_{\rm HS} < \Pi_{\rm FC}$ | $(1+\lambda)^{\frac{1}{1-\alpha}} < \frac{3}{2}$ | $\oslash$ |
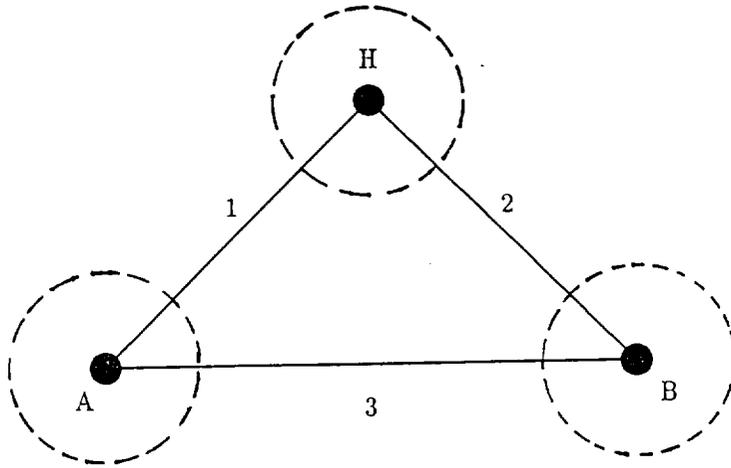
Figure 1: Fully-Connected (FC) Network and Spatial Environmental Impacts - Base Case
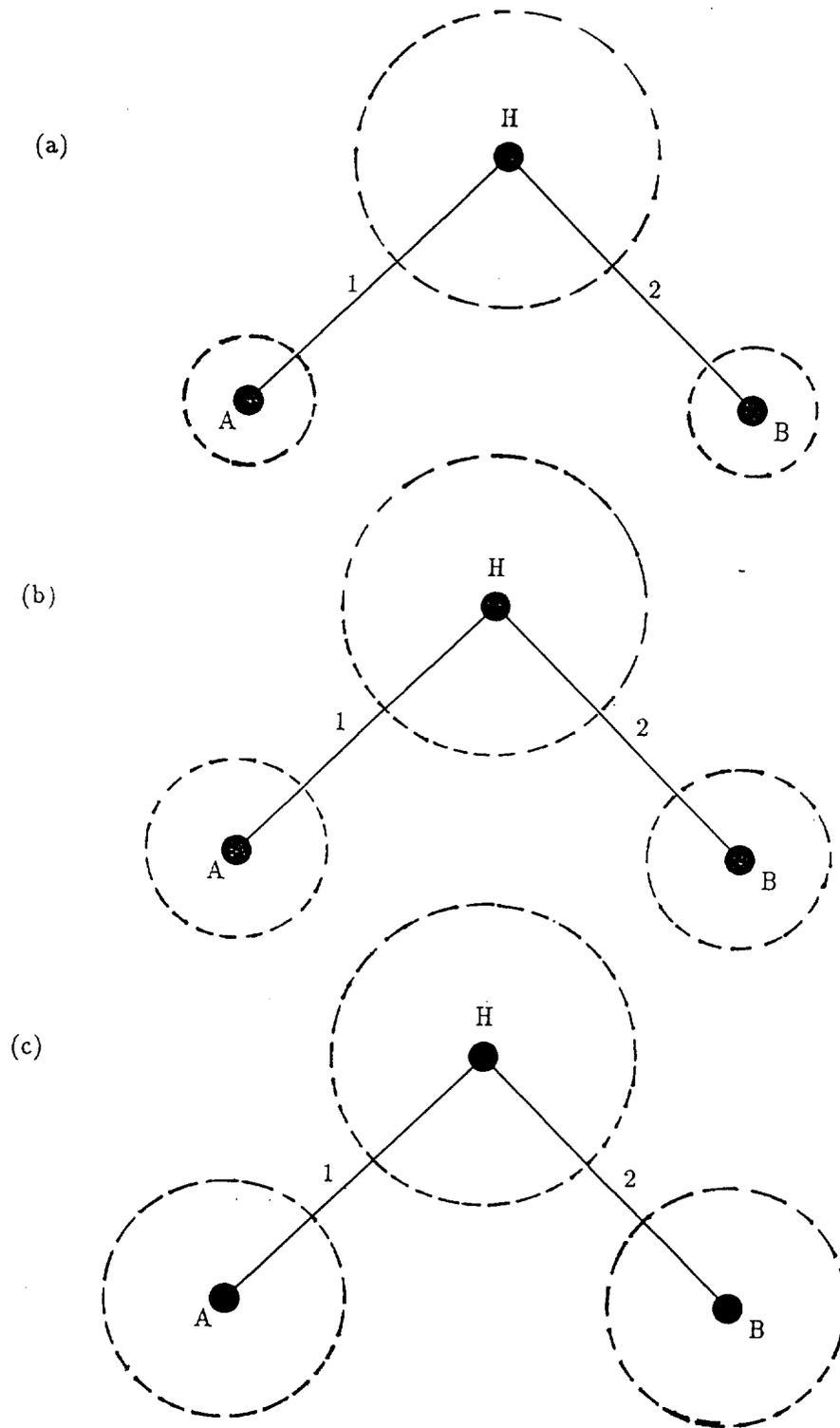
Figure 2: Hub-and-Spoke (HS) Network and Alternative Environmental Impacts

Input

Proposed environmental levy

Basic conditions

Supply-demand

Carrier impact

Higher operating costs

Market structure

Monopoly versus oligopoly

Carrier response/change

Short run: fares;
Medium run: schedule-network;
Long run: fleet mix and technology

Performance

Efficient air transport services ?
Higher social welfare by including
externalities into total airline costs ?

Figure 3: Conceptual Model for Estimating Impact of Environmental Levy

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# AIRPORT FINANCING AND USER CHARGE SYSTEMS IN THE U.S.A.

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# 1. INTRODUCTION

This paper examines the financing of U.S. public airports in a turbulent era of change, and projects toward the future. It begins by briefly outlining historical patterns that have changed the industry, and airport facilities in particular. It then develops basic principles of public finance as applied to public infrastructure, followed by the applicable principles of management. Following that, the current airport financing system is analyzed and contrasted with a socially optimal financing system. A concluding section suggests policy reforms and their likely benefits.

The principles of finance and management discussed here are elementary. However, their implications are radical for U.S. airport policy. There is a great deal of room to improve the allocation of aviation infrastructure resources. The application of these basic principles makes it evident that in many cases, current practice is wasteful, environmentally unsound, overly costly, and inequitable. Future investments in public aviation capital will continue to be wasteful until more efficient pricing systems are instituted. Thus, problem in the U.S. is not one of insufficient investment in airport infrastructure, but investment in the wrong types of infrastructure.

In the U.S., the vast majority of publically-owned airports are owned by local governments. Thus, while the federal government had a great deal of influence in financing airports, ultimately these are local decisions. The same is true with many other public infrastructure issues. Katz and Herman (1997) report that in 1995, U.S. net public capital stock equaled almost $4.6 trillion, 72% of which ($3.9 trillion) was owned by state and local governments, most of it in buildings, highways, streets, sewer systems, and water supply facilities. Thus, public infrastructure finance is fundamentally a local government issue, with implications for federal and state governments in the design of their aid programs.

# 2. HISTORICAL PATTERNS IN U.S. AVIATION

Historically, the goal of U.S. aviation policy was to stimulate the development of the industry. The 1926 Air Commerce Act declared the role of the federal government to promote aviation for commercial transportation. In 1946, the Federal Airport Act authorized federal aid to airports, and financed almost half of all capital spending on airports between 1947 and 1969 (Congressional Budget Office, 1988). In 1970, the Airport and Airway Development Act established the Airport and Airway Trust Fund (AATF). This earmarked certain federal revenues for deposit into the trust fund which then supported certain expenditures. The AATF is currently funded by an excise tax on tickets for domestic flights, a new per passenger fee on domestic flight segments, an excise tax on domestic cargo, taxes on international departures and arrivals, and taxes on aviation gas and jet fuel. Flights beginning or ending at rural airports are not assessed the flight segment fee, and pay a reduced ticket tax until 1999. Expenditures from the AATF support grants-in-aid for public-use airports, and partially

support Federal Aviation Administration (FAA) operations including air traffic control, mapping and weather information, pilot training and certification, aircraft inspection, FAA facilities and equipment, and research and development related to general aviation and safety. The grants-in-aid fund local airport safety, planning, construction, and rehabilitation projects. These grants fund these activities at percentages ranging from 65% to 100% of project costs.

The Airline Deregulation Act of 1978 turned the industry upside-down, and signaled a shift away from public regulation and control of the industry. This shift was accelerated during the Reagan Administration which attempted to privatize, or at least "de-federalize" many airports. The Bush and Clinton administrations have continued this policy. In 1994, President Clinton issued Executive Order 12893, directing federal transportation agencies to use market pricing, cost benefit analysis, and increased private participation in infrastructure investment and management (Truitt and Esler, 1997). Thus, what had formerly been essentially a mercantilist approach to the industry with extensive government involvement at all levels, is becoming a more laissez-faire approach.

Deregulation and privatization are sweeping the world, and this trend is affecting U.S. transportation in fundamental ways also. As Lockwood (1997) describes, U.S. transportation institutions were formerly characterized mostly by monopolized, tax-dependent agencies with federally-determined standardized approaches, and a classic Weberian bureaucratic organization with limited incentives for performance improvement or consumer responsiveness. They are in the process of shifting toward enterprises which draw their revenue from priced services, relying on market feedback with varied approaches to problems, and a more fluid, consumer-responsive organizational structure. These broad implications will not affect all airports right away, but the trend is undeniable. As with the airlines that faced deregulation twenty years ago, the airports that have the greatest adaptive capacity will survive. Others will not.

One of the most important arguments against this trend is the desire to maintain a national system of air travel facilities. It is argued that reliance on market mechanisms rather than government planning will leave areas with unprofitable airports without vital air service, and will endanger the nation's world class network of airports that benefits all citizens, not just users. Federal grants support between 75% and 80% of the investment funds at general aviation airports, compared to between 20% and 25% at large and medium hubs (Congressional Budget Office, 1988). Thus removing or reducing this subsidy would seriously threaten many general aviation airports, possibly cutting off certain low density areas from air service. This argument is essentially a recapitulation of the mercantilist perspective, with a dash of socialism. While not unpersuasive, one has to question its practicality in the U.S. today. Currently there are 17,451 airports in the U.S., 11,853 of which are closed to the public, and 5,598 of which are open to the public. Only 4,169 of the public access airports are publically owned (Truitt and Esler, 1997). Even a large decline in the number of publically-subsidized airports would still leave thousands of private facilities.

Certain areas might be better served by closing certain smaller airports and consolidating operations into a larger, regional facility. Local communities that are loath to lose their airports would have to look to their own tax resources to fund them. This change is likely to be fairer than relying on federal taxes to fund local projects. Finally, while citizens do benefit from a national system of airports, as with any good or service, the question is, how does that benefit compare to the opportunity cost of these resources? When there are other modes that are close substitutes, as well as private alternatives, one has to question the need for federally-subsidized airports.

The central question addressed here is, how should the system of financing airports be changed in the face of this environmental transformation?


## 3. BASIC PRINCIPLES OF FINANCE


### 3.1 Equity

There are two principles of **equity** in public finance. First, that the costs of government should be distributed in proportion to the benefits received (the "benefits received" approach), and second that the costs should be distributed according to the ability of citizens to pay (the "ability to pay" approach). These two principles are both compelling. Their propriety depends on the specifics of the service. The benefits received approach is most appropriate where services are distributive, specific to certain identifiable persons or areas, and when service use can be measured. The ability to pay approach is more appropriate when the service is redistributive in nature, broadly realized, and difficult to measure. As airports are distributive services that are specific and largely measurable, the benefits received principle is generally the more compelling one. Thus, an equitable airport financing system would charge users according to their benefits received.


### 3.2 Efficiency

The benefits received principle of equity aligns closely with the principle of **economic efficiency**, that price should be set equal to the marginal social cost attributable to the user. An efficient price ensures that users value the good as much or more than the value of the additional resources used up in producing it. Further, services provided on a user fee basis will typically cover the costs of provision. The costs of production will be covered by revenues from a marginal cost pricing system if the industry is not a natural monopoly, that is, an industry where average costs are always declining. Where it is a natural monopoly, there are a variety of pricing strategies that involve trade-offs among the goals of efficiency, cost recovery, and maximization of social welfare.

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Marginal cost pricing in its strict form may differ from benefit-based pricing. The former implies one price for all users, while the latter may imply different prices for each user. There are a variety of possible pricing approaches, such as perfect price discrimination, two-part tariffs, and "Ramsey prices." The equity and efficiency characteristics of these differing pricing systems vary. Their common attribute, though, is that they charge users directly for their use.

Most departures from the principle of marginal cost pricing are dangerous, as they can lead to wasteful policies that are often difficult to change. For example, if the price of electricity is subsidized at a price lower than the efficient price, a residential user would be encouraged to overuse it. The artificially low price for electricity might cause them to shift from a gas furnace to electric heat, resulting in investment in an economically inefficient capital stock. Thus, the inefficient subsidy has several unfortunate effects: it encourages the wasteful use of scarce energy, it requires a continued subsidy from the government, and it creates incentives to install inappropriate capital. While efficiency is not the only goal, departures from efficient pricing structures should be done only after the alternatives have been carefully weighed.

"User fees" of one sort or another are used for many local services. The largest revenue sources for transportation in the U.S. are taxes on fuels, such as gasoline, diesel fuel and jet fuel. For public utility services in the U.S., such as solid waste collection and disposal and water, electricity and gas supply, fees are typically assessed in a variety of ways: on a flat rate uniform basis; "incremental rates" determined by factors such as container size and frequency of collection; or by measured service, which assesses fees according to meter readings in the case of water, or the sale of bags, stickers or tags in the case of solid waste (Hawkins, 1991).

## 3.3 External Costs and Benefits

In some cases there may be "spillovers" of benefits or costs from one community to another. For example, an airport in city A might also serve residents of city B. If city B is not involved in the decision about the financing and design of the road, the decision may not be equitable or efficient for society as a whole. Further, if the residents of many other cities are affected by the airport, the difficulty of negotiating a satisfactory solution compounds. One simple solution is for either the state or federal government to allocate a grant to encourage the appropriate level of investment. However the Coase theorem tells us that this commonly suggested solution is only one possibility. Others include widening the scope of decision-making to include both A and B, side payments from B to A, or even reliance on the tort liability system to allocate the right of action to either party.

Current federal infrastructure grants to airports and other projects typically use relatively high federal shares, some as high as 100%, and are capped at relatively low dollar amounts. As Gramlich (1994) points out, these grants do not provide the necessary marginal stimulus, yet are more costly than they need be. As Gramlich writes, "the correction is obvious — lower

federal matching shares and remove the caps." (1994, 1191).

Federal aviation grant policy should be reformed in concert with the goals of efficiency and equity. Granting agencies should require efficient pricing where administratively feasible. Grants should not assume that all localities need the most technologically advanced system, but rather should flexible, encouraging low cost systems able to reliably supply the appropriate level of service. Finally, they should employ matching formulas that are generally lower and closely related to the proportion of the spillover. This might require a customized approach that calls for federal agencies to first examine the specifics of local situations, then recommend financial packages following broad agency guidelines, as opposed to the current "one size fits all" approach.

More fundamentally, one might question whether there should be any federal grants to local airports. Grants for airport construction, rehabilitation, and planning generally do not fit the criteria of correcting for a positive externality. Those for safety may. Further, current federal policy subsidizes low-use airports more than high-use airports. The low-use airports generate the fewest external benefits, which is the opposite of what theory recommends.

Another justification for grants is as a subsidy to low-income communities. In certain situations it might be justifiable to give an infrastructure grant to a low-income area, however it is usually more effective to subsidize low income people directly rather than hoping that funds granted to local governments seep down to needy people. In general, it is unlikely that aviation services serve critical needs of low income people, as this group generally does not travel by air, and air freight can be transported by other substitute transportation modes.

Thus, the theoretical justification for federal airport grants is weak. With the possible exception of safety grants, it is likely that a fairer and more efficient policy would be to allow states or local governments to tax and spend as they desired on these projects.


## 3.4 Optimal Financing Policy

In general, an efficient and equitable approach to financing airport projects is by unsubsidized user fees set at an efficient price. Projects may initially be financed by bonds which can allow for the costs of the project to be paid by user charges over the useful life of the facility; an approach Mikesell (1995) terms as "pay as you use" rather than the "pay as you go" method of cash financing. In general, price subsidies run the danger of wasting dollars and resources, as well as encouraging inefficient installation and use of capital stock.

This socially optimal financing system differs greatly from current policy. As will be described in more detail, current policy stresses cost recovery, and does not fit with either the criteria of efficiency or equity. Further, federal grant policy is wasteful, as it subsidizes local projects whose benefits are low relative to the federal expense of providing them. Local

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governments use a variety of fees and charges. Since 1983, fees and charges have been the fastest growing component of local government revenues in the U.S. (U.S. Department of Commerce, 1982-83 and 1993-94). Despite this, local government pricing tends to be *ad hoc*, and ere is ample room for improvement.

## 4. MANAGING INFRASTRUCTURE

An appropriate infrastructure policy is focused on three intertwined aspects of management: system design, finance and planning.

Infrastructure systems should be designed for an efficient size, that is, a size that provides the level of services desired by the community as measured by their willingness to pay the marginal social cost of the good or service. With an efficient price, the resulting demand dictates current system capacity. Once designed, facilities should produce output at the lowest possible cost per unit. This does not necessarily imply a "cheap" facility. Costs should be kept low by making the appropriate changes in technology and substituting capital, land and labor for each other as appropriate. The costs of the system will typically be covered by the user fee, which is the first step toward a rational policy. Fees must be collectible, which generally requires fees, tolls, or other user charges. In some cases, certain charges may have high administrative costs, presenting a trade-off that would challenge the attainment of a well-managed system. The second step is to ensure that user charges equal the marginal cost of the service.

Once an efficient price is set and an appropriate facility put in place, planning becomes easier. Expansion or improvement of infrastructure is justified when it either reduces long-run costs, or when consumers are willing to pay for the improvement in either quality or capacity. The attractiveness of any development can be judged using efficiently determined values. Development then should be able to pay for itself and be financially sustainable for the long-term.

## 5. FINANCING AVIATION INFRASTRUCTURE *

In aviation, as well as with other modes of transportation, U.S. federal policy is a complex, mixed public-private financing system that typically taxes economic activities related to use, the proceeds of which are deposited into a trust fund which finances a variety of public activities supporting the industry. State financial policy typically mirrors federal policy, while operations are carried out at the local level. Local governments tend to be parochial, focusing on projects thought to enhance local economic development and relief of congestion. Policy is therefore made by millions of actors in thousands of different governments with divergent interests.

What have been termed "user charges" are in only the loosest sense of the term. Various users pay certain fees and taxes, but the amount they pay is unlikely to reflect the cost of their use the way a private price would. Certain users benefit from large subsidies paid for by other users or the general taxpayer. Further, certain non-pecuniary social costs, such as pollution, are not paid by those causing them. Aviation fits that pattern, as do highways, and waterways.

## 5.1 Federal Finances

The main federal expenditures are for FAA activities, in particular air traffic control (ATC). Among the taxes described above, most are not closely related to the relevant private and social costs. The FAA's costs are related to the number of air route traffic control centers an airplane moves through, the number of take-offs and landings, and the use of weather and mapping information. Taxes related to the number of passengers (such as the international departure and arrival taxes) and the fares they pay (such as the ticket tax) do not reflect these costs well (Congressional Budget Office, 1992). The fuel taxes have some relationship to ATC costs, as fuel use is correlated with distance traveled, which in turn is loosely related to the use of ATC services, but this relationship is weak and does not send appropriate price signals. Similarly, the cargo excise tax is not closely related to ATC costs. The segment tax would be a reasonable proxy if the fee was assessed per aircraft rather than per passenger. An even more direct charge would be one based on the operation of each aircraft and the services used.

Congestion in the airways is a social cost caused by air traffic, and landing fees related to congestion could efficiently charge for that cost. Air pollution and noise are other social costs that should also be recovered through the federal tax system. Again, these taxes should be based per plane, rather than per passenger, as an empty plane causes as many of these costs as does a full one. Fuel taxes are appropriate taxes to internalize the cost of air pollution, but should not be deposited into the AATF which subsidizes more travel. Either landing fees or possibly a reformed segment tax could charge appropriately for noise pollution. However, because there are increasing returns to scale in the ATC system, marginal cost pricing would lead to less than complete cost recovery (Congressional Budget Office, 1992). There are a variety of ways to address this issue, most involving a trade-off between efficiency and cost recovery.

## 5.2 Financing Local Airports

Most airports providing civil air transport in the U.S. are owned by counties or municipalities. In some cases, airport authorities operate as separate special districts. An authority's members may either be publicly elected or appointed. Thus, although they are often seen as separate quasi-public entities, their finances are linked with that of their parent government.

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The financing of local airports is diverse and complex. Fees charged are based on costs incurred. In most cases, one of two methods of allocating costs is used: the compensatory cost approach or the residual cost approach. The compensatory cost approach charges facility users (typically airlines) fees to recover total cost based on their use and occupancy of specific airport facilities, such as a portion of a terminal wing. The airport then uses other revenue sources to pay for the costs associated with common areas. The residual cost approach charges users a share of the net cost of the airport (the "net revenue requirement") after subtracting other revenues from total costs. Landing fees are calculated based on the net revenue requirement. In cases where other airport revenues (such as rentals and concessions) are particularly high, landing fees can be quite low or even zero (Ashford and Moore, 1992). The main difference between the two is that under the compensatory cost approach, an airport's revenues might be greater or less than its costs, while the residual cost approach revenues are adjusted to equal total costs.

Both the compensatory cost approach and the residual cost approach are variants of an average cost pricing system, not unlike the cost allocation system used for by the Federal Highway Administration for highways. This approach ignores the importance of the signals prices send to producers and consumers. Although cost allocation is presented as a user financing approach, this is only true in the sense that cost allocation methods make *post hoc* calculations of the amounts that different groups of users pay relative to the costs they cause. Even if these calculations found that each group paid its share, within groups certain users may underpay and others may overpay. Further, this approach does not incorporate potentially substantial non-pecuniary costs, such as noise. The residual cost approach in particular inappropriately reduces landing fees if other airport revenues are high. Landing fees should be set based on the congestion costs caused by each take-off or landing, the social costs of noise pollution, and any direct costs to the airports for capital costs and maintenance. Marginal cost pricing is compatible with cost recovery in most cases, as airports tend to be characterized by constant returns to scale (Winston, 1991). Thus marginal cost pricing would allow airports to be financially self-sufficient, weaning them away from federal grants as a source of capital funding.

The focus on cost recovery is inappropriate. Only where an airport exhibits constant returns to scale might an average cost pricing method be efficient. This inefficiency is not just an academic concern, it has serious, and quite visible implications for resource use. It is also inequitable not to charge users for the social costs of air and noise pollution that they cause, or to subsidize general aviation with taxes on commercial passengers. Further, like any other capital project, an airport that cannot be financially sustained with user charges and local taxes apparently has costs that exceed benefits, and thus is of questionable propriety.

## 5.3 Local Tax Policy

To recover costs, airports generally levy three types of user fees on aircraft and their

passengers: landing fees for the use of runways, taxiways, and landing strips; passenger facility charges (or "head taxes"); and apron parking fees for aircraft. Landing fees are generally based on aircraft weight, although at some smaller airports, flat-rate fees are common. Passenger facility charges (PFCs) are based on the number of passengers on the airplane. They are similar to passenger load supplements, which are common in Europe. Aircraft that park on aprons are typically charged fees. Other common fees are for terminal concessions and leased areas, such as offices, cargo areas, and ticket counters.

Passenger facility charges are growing as a revenue source. Fisher (1996) notes that from 1992-93, 161 airports had PFCs approved by the FAA that would raise an estimated $9 billion of revenue. However PFCs suffer from the same problems as federal ticket taxes and international departure and landing fees, as they vary with the number of passengers, rather than the number of aircraft. The marginal cost of landing is not increased by the number of passengers. Current landing fees also are inefficient. At busy airports, one of the main costs imposed on an airport by an aircraft is the delay caused other planes; as a result, weight-based landing fees are inferior to congestion-based landing fees. Weight-based landing fees might be a reasonable method for uncongested airports, although a charge directly related to the services used would be better.

Congestion fees are common in Britain (Ashford and Moore, 1992). Their imposition in the U.S. would shift the burden of taxation among users. Winston (1991) argues that if the congestion fees were used to add runways at busy airports, the net benefits of this change would be especially large and widespread. Reduced delays would benefit both passengers and carriers, and airports would receive congestion fees which would roughly balance the investment required in the runways. General aviation would face higher landing fees, but if they adjusted their usage to avoid congested airports during peak arrival and departure times, the impact of these fees would lessen. If the additional investment in runways was not made, landing fees would result in a redistribution from passengers to airports.

Clearly, there are many opportunities to improve the current aviation tax system. The current system is neither equitable nor efficient. Changes in pricing methods have important long-term implications for resource use. The most politically unpopular aspect of the change proposed here would be the loss of revenue to general aviation airports and smaller commercial airports. Many citizens would be concerned if their local airport was closed or services reduced. But as different modes of transportation are substitutes for each other, shifts in the financing of airports affect other modes. Subsidies and inefficient pricing systems cause long-term misallocation of resources, inhibiting long-term economic development.

## 6. BENEFITS OF REFORM

While it is perilous to predict the future, the trend in U.S. aviation is clearly away from public sector monopoly and toward private sector competitive arrangements. Federal taxes that

support trust funds and in turn, grants to local airports, are likely to continue for at least the near future. However, controversy about the allocation of these funds among airports, as well as decreased general aviation traffic, is already changing the characteristics of air traffic and airports. This will create financial pressure, especially on the low-volume airports and their constituents. Ultimately, localities will have to decide between variants of the old public monopoly model and the new quasi-private enterprise model.

Part of the problem is that policy is too centralized, with a large share of local airport revenue derived from federal grants. The federal taxes in place do not achieve the goals of efficiency and equity. As discussed, the grants do not serve economic goals well; nor do they serve political goals, except perhaps to maintain the *status quo*. Further, airports differ widely, and different facilities have different needs. To serve these needs, a logical response would be to make local airports more financially independent. Local, rather than federal, tax dollars would be used to support local airports. Resource allocation decisions can be made much better by local managers comparing the costs and benefits of specific airports or projects instead of federal administrators. Large, congested airports could make their own decisions about whether to impose congestion fees or whether to build additional runways, while smaller airports would also make their own pricing and investment decisions. Decisions about whether to increase taxes to support an otherwise unprofitable airport would be made by the citizens of the locality.

Pricing issues will be a central question in this decision. A more efficient pricing system is anything but inevitable. Federal policy will be critical in shaping the decision, as will state and local decisions. With inertia as the main force currently determining airport financial policy, the U.S. is likely to go bumping along from one financial crisis to the next. Instead of this, there is a great deal to be said for the model of optimal pricing sketched out here.

The pattern is clear. The U.S. approach to financing airports, as with other modes of transportation, creates glaring inefficiencies that waste a substantial amount of government revenue, time, and environmental capacity, and tends to build the wrong sized airports in the wrong places. Improved user fees are not difficult to implement, and though they may present challenges in terms of administrative costs and political acceptability, these problems are not serious. Further, as a result of the public's resistance to increased property taxes or further adoption of local non-property taxes, user fees now appear to be the path of least resistance for local governments. Reform of federal aid can also create better incentives and reduce federal aviation taxes substantially.

The adoption of improved local user fees not only would create an additional source of revenue that could replace existing federal taxes, but they also can do an impressive job of reducing expenditures, and allowing for more effective management of service responsibilities. The benefits of moving to an improved user-fee system to finance airports are many:

- Lower cost of investment in infrastructure, and a source of information to guide airport officials about the allocation of public funds to various projects (Gramlich, 1994).

- In many cases, facilities will be self-financed through user fees, rather than relying on federal grants, local taxes, and debt. Some airports that are not financially sustainable without federal grants, and whose citizens are not willing to pay for their costs may not merit continued operation. These would probably be replaced by consolidated regional airports and private facilities.

- Charges that more closely correspond to the benefits users receive from these services, achieving a more equitable system.

- More appropriate facility size and quality with lower long-run maintenance costs, leading to a longer facility life and reduced congestion.

- Better incentives for pollution reduction and conservation of fuel.

- State and federal grants can get the most "bang for the buck," that is, that stimulate the appropriate technology at the lowest long-term cost to society.


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# OPTIMAL DEMAND FOR OPERATING LEASE OF AIRCRAFT

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# ABSTRACT

Operating lease of the aircraft gives the airlines flexibility in capacity management. However, airlines pay a risk premium to the leasing companies for bearing part of the risks. Therefore, the airlines face a trade-off between flexibility of capacity and higher costs. This paper develops a model for the airlines to determine their optimal mix of leased and owned capacity, taking into consideration that the demand for air transportation is uncertain and cyclical. Empirical results based on the model suggested that the optimal demand by 23 major airlines in the world would range between 40 to 60 percent of their total fleet, for the reasonable range of premiums of operating lease. For the leasing companies, this indicates huge potential of the market given strong forecast for the growth of air transportation in the next decade.

# 1 INTRODUCTION

Lease of aircraft has become an increasingly important tool for the airline industry. According to recent estimates, approximately one-half of the world's aircraft fleet is operating under some kind of lease. Within the lease option, there is an increasing trend in favour of short-term operating lease. For example, Gritta, Lippman, and Chow (1994) reported that, for a sample of major US carriers, percentage of planes leased increased from 19% in 1969 to 54% in 1991 and the percentage of aircraft under operating leases to total leased aircraft increased from 13% in 1969 to 82% in 1991.

The benefits of lease were traditionally viewed as financial. Gritta, Lippman, and Chow (1994) examined the role of lease as sources of off-balance-sheet financing. As operating lease is not capitalized, air carriers can substantially lower their debt/equity ratio on their balance sheet if they finance their aircraft fleet by leasing rather than by traditional debt. Another well-known financial benefit is that leasing separates the ownership of an aircraft from the aircraft's user. Therefore, it is the lenders (lessors) who own the aircraft while the airlines (lessees) operate the aircraft. This separation of ownership enables valuable depreciation allowances to be used more effectively by the lessors for tax purposes. Indeed, in certain international leasing arrangements, when the lessors and the airlines belong to different tax regimes, it was reported that depreciation allowances were claimed by both parties in the leasing contract, a practice commonly referred to as "double dip".

It may be argued that the effects of off-balance-sheet financing is largely cosmetic because financial analysts would not be fooled when it is publicly known that an airline has taken up a substantial lease obligation. Indeed, Marston and Harris (1988) demonstrated, using a large sample of US firms, that lease and debt are substitutes as it would under efficient financial markets. Results from a survey study by Bayliss and Diltz (1986) also showed that bank loan

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officers reduce their willingness to lend when a firm takes up lease obligations. Therefore, lease as sources of off-balance-sheet financing does not appear to be able to significantly increase firms' debt capacity. Furthermore, with increasingly stringent accounting and tax rules, the tax effects of lease are also limited. Now, the major attractions of operating lease of aircraft are viewed as more operational than financial in nature. First, while the aircraft manufacturers currently have substantial order backlogs, major aircraft leasing companies have inventories for immediate delivery. Hence, airlines desiring a quick expansion need not wait for the production backlogs. Second, short-term operating lease provides the flexibility to the airlines so that airlines can manage fleet size and composition as closely as possible, expanding and contracting to match demand.

While significant use of operating lease affords the airlines with the flexibility to change aircraft fleet size as demand for air transport changes, it created a burden to the leasing companies to maintain efficient utilization of their inventory of aircraft. In a recession, when demand for aircraft is low, the leasing companies will also suffer from excess capacity. Indeed, the last recession was devastating to dozens of leasing companies when demand and aircraft values dropped. In essence, through the flexibility of operating leases, the airlines shifted part of their business risks to the leasing companies. However, although short-term operating lease reduces the risks of excess capacity for the airlines, it does not eliminate uncertainties in the financial costs. During recession, when costs of short-term leasing are low, airlines have little incentive to expand their fleet. On the other hand, during booming period, when the airlines need the capacity most, the costs of leasing will also be highest. Thus the operating lease provides a vehicle which enables the airlines and the leasing companies to share the risks of uncertain demand. For the airline industry which faces a cyclical demand, this risk-sharing aspect of operating lease is highly desirable.

Needless to say, the aircraft leasing companies are in the business for profits. They purchase aircraft from the manufacturers with means of long-term financing, and then lease the aircraft to the airlines. For short-term operating lease, it would take at least two or more lease

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transactions on an aircraft for the leasing companies to recover the costs. Therefore, the expected revenues from operating lease must not only cover the long-term financing costs of the aircraft, but also provides the leasing company with a profit (premium) adequate to compensate for the risks involved with aircraft release and residual value.

To the airlines, optimal use of operating lease then presents the problem of a trade-off between operational flexibility and higher financial costs inherent in the short-term lease. The historical trend has been an ever-increasing use of operating lease, in tandem of the development of an active aircraft leasing market. Now, with the market becoming mature, whether airlines should continue to increase reliance on operating leases has become a strategic question to the fleet management of the airlines.

This paper examines the lease/own decision from the airlines' standpoint. However, the results will also be valuable to the leasing companies because the airlines' decisions on the aircraft lease directly affect the profitability of the leasing companies. In section 2, we derive optimality conditions, relating owned capacity, leased capacity, expected traffic demand to premiums of operating lease. In section 3, we examine empirically the world's major airlines' optimal demand for operating lease of the aircraft. Section 4 concludes.

## 2 MODEL

Consider an airline. The airline faces an uncertain demand $y = y(\tau)$, where $\tau$ represents future state of nature. The capacity of the airline is $Z = K + S$, where $K$ is the capital stock owned or leased for long-term, $S$ is the capital stock leased for short-term. $K$ is inflexible in the sense that once acquired, it cannot be easily disposed of, whereas $S$ is flexible in the sense that it can be obtained any time as needed. For simplicity, we will call long-term leasing as capital leasing and

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short-term leasing as operating leasing.[1]

The airline's profits can be expressed as

$$\pi = R[y(\tau), Z] - V[y(\tau), Z] - w_k K - w_s(\tau) S$$

where R is the revenue, V is the variable cost, $w_k$ and $w_s$ are the costs of long-term capital and short-term capital, respectively. Note that $w_k$ is known at the beginning while $w_s$ depends on the future uncertain state. The airline's capacity decision is made in two stages. In the first stage, the airline acquires the long-term capital through either purchasing or capital leasing. Then, in the second stage, after the state of nature is revealed, the airline acquires additional capacity, if necessary, through operating leasing.

In the first stage, the airline determines K to maximize its expected profits, i.e.,

$$\max_K E\{R(y, Z) - V(y, Z) - w_k K - w_s S\}$$
$$= \max_K \int [R(y, Z) - V(y, Z) - w_k K - w_s S] f(\tau) d\tau \tag{1}$$

where K and S are nonnegative. Then, in the second stage, when K is fixed and the uncertain state, $\tau$, is revealed, the airline chooses the amount of operating lease, S, to maximize profits conditional on K and $\tau$. We assume that the following second order condition is satisfied over all the states:

$$\frac{\partial^2 R}{\partial Z^2} - \frac{\partial^2 V}{\partial Z^2} < 0. \tag{2}$$

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[1]By textbook definition, if the term of a lease covers a major portion (e.g. 75%) of the economic life of the equipment under the lease, the lease is a capital lease; anything shorter is an operating lease. However, in the aircraft leasing market, although the economic lives of aircraft may be as long as 20 to 30 years, typical operating leases are short-term (e.g. 5 years or under). In this paper, we focus on short-term leases only.

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This condition states that the marginal effects of capacity on revenue and variable costs are diminishing as capacity increases.

In the second stage, given the capacity K and the state $\tau$, the airline's problem is

$$\max_{S} R(y, Z) - V(y, Z) - w_K K - w_s S$$

Let

$$T_1 = \left\{ \tau \left| \left[ \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s \right]_{S=0} \geq 0 \right. \right\},$$

$$T_2 = \left\{ \tau \left| \left[ \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s \right]_{S=0} < 0 \right. \right\}.$$

(3)

Then, the optimal solution $S^*$ is zero, if $\tau \in T_2$.

If $\tau \in T_1$, the optimal solution $S^*$ is implicitly determined by the following first order condition:

$$\frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s = 0.$$

(4)

Differentiating the above equation with respect to K gives:

$$\left( \frac{\partial^2 R}{\partial Z^2} - \frac{\partial^2 V}{\partial Z^2} \right) \left( 1 + \frac{\partial S^*}{\partial K} \right) = 0.$$

Thus, in sum, we have

$$\frac{\partial S^*}{\partial K} = \begin{cases} -1, & \tau \in T_1, \\ 0, & \tau \in T_2. \end{cases}$$

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In the first stage, the first order condition to determine K is

$$
\int \left[ \left( \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} \right) \left( 1 + \frac{\partial S^*}{\partial K} \right) - w_k - w_s \frac{\partial S^*}{\partial K} \right] f(\tau) \, d\tau = 0. \tag{5}
$$

Substituting and rearranging gives:

$$
\int_{T_1} (w_s - w_k) f(\tau) \, d\tau + \int_{T_2} \left( \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_k \right) f(\tau) \, d\tau = 0,
$$

or,

$$
\int (w_s - w_k) f(\tau) \, d\tau = -\int_{T_2} \left( \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s \right) f(\tau) \, d\tau. \tag{6}
$$

From (3), the right hand side of (6) is positive. Hence,

$$
\int (w_s - w_k) f(\tau) \, d\tau = E(w_s) - w_k > 0.
$$

This inequality has an intuitive interpretation. From the standpoint of the leasing companies (lessors) which own capital stock and then lease to airlines, short-term operating lease is riskier than long-term capital lease due to uncertainties in the future terms of lease. Therefore, the above inequality shows that leasing companies should expect to earn a positive risk premium on operating lease.

Overall, equation (6) shows the trade-off between owning and leasing capacity from the standpoint of the airline. On one hand, a marginal increase of owned capacity reduces expected capital cost; on the other hand, since owned capacity cannot be disposed of when demand is low, a marginal increase of owned capacity increases the expected costs of excess capacity. The optimal mix of owned and leased capacity then constitutes a balance between these two costs.

The optimality condition (6) determines the airlines' optimal mix of owned and leased capacity, thereby the condition can be used to forecast airlines' demand for operating lease of the aircraft. Needless to say, the ability to forecast such demand is highly valuable to the leasing companies as well.

In this section, we illustrate the use of condition (6) by considering the optimal demand for leased capacity from twenty-three of the world's major airlines.

*Methodology*

We start with estimating a variable cost function for the airlines. The cost function may be written as follows:

$$V = V(Y, W, Z, D)$$

where Y is output, W is the vector of the prices of variable inputs, Z is total capacity, and D is a vector of operating characteristics. Based on the estimated cost function, we take the expectation of the right-hand side of (6) conditional on Z to obtain

$$G(Z) \equiv -E\left\{\frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s \mid \tau \in T_2\right\} \tag{7}$$

For given expected premiums on operating lease, $E(w_s) - w_k$, the optimal owned capacity for each airline, $K^*$, can be solved by equating $G(Z)$ with $E(w_s) - w_k$. Then, comparing $K^*$ with the total capacity gives the optimal demand for leased capacity.

For empirical specification, we use the conventional translog functional form for the variable cost function, namely,

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$$
\begin{aligned}
\ln V = a_0 &+ \sum a_i G_i + \sum a_{T_i} T_i + \sum a_{D_i} \ln D_i + a_Y \ln Y + a_Z \ln Z \\
&+ \sum a_{W_i} \ln W_i + .5 b_Y \ln Y \ln Y + .5 b_Z \ln Z \ln Z + .5 \sum b_{ij} \ln W_i \ln W_j \\
&+ \sum b_{Y_i} \ln Y \ln W_i + \sum b_{Z_i} \ln Z \ln W_i + .5 \sum c_{ij} \ln D_i \ln D_j \\
&+ \sum c_{Y_i} \ln Y \ln D_i + \sum c_{Z_i} \ln Z \ln D_i + \sum e_{ij} \ln W_i \ln D_j
\end{aligned}
\tag{8}
$$

where the vector of operating characteristics $D_i$ consists of load factor and the average stage length, $T_i$ is the time dummy capturing effects of technical change and $G_i$ is the regional dummy differentiating airlines headquartered in different continents (North America, Europe, and Asia and Oceania). There are three variable inputs: labour, fuel, and materials. As standard practice, two of the three variable cost share equations are estimated jointly with equation (8).

Taking into account the flexibility of the short-term capacity expansion afforded by operating lease, (3) and (5) give the following optimality condition for the total capacity of an airline:

$$
\frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s \leq 0
\tag{9}
$$

where inequality holds if capacity is rigid and excessive. Rewrite (9) as

$$
w_s \geq \frac{R}{Z} \frac{\partial \ln R}{\partial \ln Z} - \frac{V}{Z} \frac{\partial \ln V}{\partial \ln Z}
$$

or

$$\frac{w_s Z}{V} = \frac{R}{V}\eta - \frac{\partial \ln V}{\partial \ln Z} + u \qquad (10)$$

where $\eta$ is the elasticity of revenue with respect to capacity and u is a non-negative error. Note that $\eta$ is related to the elasticity of travel demand with respect to airline's scheduled frequency (See, for example, Morrison and Winston, 1986; Oum, Zhang, and Zhang, 1995, for further discussion). Since u is caused by rigid capacity which cannot be adjusted downward in short-run, we assume

$$u = e_1 rig + e_2 rig^2$$

where *rig* is the share of owned capacity out of total capacity (owned plus leased) which reflects the rigidity of the capacity. $e_1$ and $e_2$ are coefficients to be estimated.

Following standard procedure, all variables in the cost function except the dummies are normalized at the respective sample means. Equations (8), (10) and two of the three variable cost share equations are then jointly estimated by a maximum likelihood method after standard normal disturbance terms are appended to each of the equations. The parameters of the cost function are then used to forecast the optimal demand for operating lease by the airlines.

*Data*

Our data sample consists of annual observations on 23 major international airlines over the 1986-93 period.[2] The airlines in our sample are chosen mainly on the basis of availability of consistent

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[2]For Cathay pacific and ANA we were able to compile the data only from 1988, and for KLM and Swiss Air, only to 1992.

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time-series data. The data is compiled mainly form the Digest of Statistics series published by the International Civil Aviation Organization (ICAO). Some additional data is obtained directly from the airline companies. The annual reports of carriers were used to supplement, cross-check with, and correct errors in the ICAO data. We contacted the airline companies for clarification when the two sources of data could not be reconciled.

The estimation of the variable cost function requires detailed data on outputs, input prices, and operating characteristics. Five categories of output data are collected from ICAO's annual publication series, Commercial Traffic[3] and Financial Data: scheduled passenger service, scheduled freight service, mail service, non-scheduled passenger and freight services, and incidental services. A multilateral output index is formed by aggregating the five categories of outputs using the multilateral index procedure proposed by Caves, Christensen, and Diewert (1982).

Five categories of inputs are considered: labour, fuel, material, flight equipment, and ground property and equipment. The price of labour input is measured by the average compensation (including benefits) per employee. Both the total labour compensation and the number of employees are collected from ICAO's annual series, Fleet and Personnel, and supplemented by data obtained directly from airline companies and from their annual reports. It was not possible to compute average hourly compensation per employee because labour hour data was not available for many of the airlines in our sample. Total fuel cost is obtained from ICAO's annual series, Financial Data, and fuel price is obtained by dividing total fuel cost by gallons of fuel consumed.[4]

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[3]Note that ICAO reports traffic data by the calendar year while reporting the financial data by the carrier's fiscal year. In the cases where fiscal year does not fall on calendar year, monthly data are used to construct the traffic data consistent with the fiscal year.

[4]Although the ICAO Financial Data reports fuel expense data, it does not report fuel price or quantity. Many airlines have provided the data on quantity series of fuel consumption upon our request. Fuel consumption for some US carriers is also collected from the Airline Monitor. The fuel quantity data for Canadian carriers are collected from Statistics Canada publications. As was done in Windle (1991), a fuel quantity regression model was used to estimate fuel consumption for those airlines whose fuel consumption data are not available to us.

For flight equipment, a fleet quantity index is constructed by aggregating 14 types of aircraft using the multilateral index procedure. The number of aircraft by type is collected from ICAO's annual series, Fleet and Personnel. The leasing price series for these aircraft types were kindly supplied to us by Avmark, Inc. and are used as the weights in the aggregation. The stock of ground properties and equipment (GPE) is estimated using the perpetual inventory method. Data on the 1986 benchmark capital stock and the net investment series are compiled from ICAO's annual series, Financial Data. The annual cost of the GPE input is computed by multiplying the GPE service price to the GPE stock. The GPE service price is constructed using the method proposed by Christensen and Jorgenson (1969) which reflects the interest rate, depreciation, and effects of taxes.

The last category of input is materials. The materials input is the residual input which is not included in any of the input categories discussed above. As such, materials cost is the catch-all cost. We compute materials cost by subtracting the labour, fuel and capital related costs from the total operating costs. The price index for the materials input is constructed using the US GDP deflator and the intercountry purchasing power parity index for GDP from the Penn World Table (Summers and Heston, 1991). The purchasing power parity index for GDP and GDP deflator together reflect a country's general price level, and are appropriate to be used as a proxy for materials price since the materials costs include numerous items. Since the GPE costs are small relative to other categories of costs, GPE costs are further aggregated into the materials costs.[5]

The variation of operating characteristics of the airlines is reflected by average load factor and average stage length of each airline in each year. The average load factor is computed as the ratio of total passenger mile to total seat mile flown. The average stage length is the average

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[5]GPE is often aggregated with flight equipment to form capital stock. However, since the purpose of this paper is to examine the optimal lease of aircraft, we decided to keep flight equipment separate from the rest of the inputs.

distance between takeoff and landing.[6]


The 23 major air carriers used in the study and the key descriptive statistics of our sample is listed in Tables 1 and 2. The variable costs are the sum of labour, fuel, and materials costs. The stock of flight equipment is used to represent capacity.


*Results*


The coefficients of the estimated cost function is reported in Table 3. Based on the coefficient on output, economies of density appears to be present at the sample mean point. According to Caves, Christensen, and Tretheway (1986), returns to density at sample mean is $(1 - a_K) / a_Y = (1 - .224) /.586 = 1.32$. However, this does not imply the presence of economies of scale which requires consideration of the size of the network of the airlines (see, for example, Caves, Christensen, and Tretheway, 1984; Xu et al, 1994; Jara-Díaz and Cortés, 1996, and Oum and Zhang, 1997, for more discussion). Since we do not have consistent data on the measurement of the size of the network of the airlines, we are unable to estimate returns to scale.


The estimated elasticity of revenue with respect to capacity, $\eta$, is about 0.05. $\eta$ is related to the elasticity of travel demand with respect to scheduled flight frequency and is identical to the latter if output price is fixed and if scheduled frequency increases in proportion to the increase in total capacity. Morrison and Winston (1986) estimated that the elasticity of passenger travel demand with respect to scheduled flight frequency was about 0.05 for leisure travellers and 0.21 for business travellers.


Regarding the operating characteristics, the first-order coefficient on average stage length

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[6]Although the number of points served is another important characteristics of an airline network, it is not included here because we are unable to obtain a consistent time series data especially for the non-US carriers. Some of the previous studies involving non-US carriers, such as Good and Rhodes (1991), Good, Nadiri, Röller, and Sickles (1993), Distexhe and Perelman (1993), and Oum and Yu (1995) have not included this variable as well.

is negative, as expected, indicating that long-haul flight is economically more efficient than short-haul flight. On the other hand, the sign of the first-order coefficient of average load factor is positive, which at first glance seems to suggest that increasing load factor while keeping all other variables unchanged would increase variables costs at the sample mean point. However, we believe that the coefficients on load factor should be interpreted with caution. Essentially, average load factor depends on output to capacity ratio; increasing load factor with both output and capacity fixed is counterfactual. Therefore, a clear interpretation of the coefficients on load factor is difficult.

To derive optimal demand for operating lease based on the estimated cost function, we still need the distribution of firm-specific demand for air transportation facing each carrier. For simplicity, we assume that the annual growth rate of demand for air service follows a normal distribution. Specifically, since the mean and standard deviation of the growth rate of our data sample are 1.094 and 0.127, respectively, we assume that the traffic demand facing carrier $I$ in year $t$ conditional on the demand in year $t-1$ has the following distribution:

$$Y_{i,t} = Y_{i,t-1}(1+\tau), \qquad \tau \sim N(\mu=0.094, \ \sigma=0.127) \tag{11}$$

Since our focus is on the optimal allocation of capacity between owning and leasing under uncertain future state, the main factor is the uncertainty in traffic demand. Hence, given the distribution of traffic demand, without loss of generality, we take all other variables as given except load factor which we assume will vary proportionally with the output to capacity ratio. Substituting (11) into (7) gives

$$G(Z) = -\int_{T_2} \left| \frac{\partial R(\tau)}{\partial Z} - \frac{\partial V(\tau)}{\partial Z} - w_s \right| f(\tau) \, d\tau.$$

Numerical integration on the right-hand-side is taken conditional on Z (For numerical integration,

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the distribution of $\tau$ is truncated to be between $\mu - 3\sigma$ and $\mu + 3\sigma$.) and then the optimal owned capacity $K^*$ is obtained by solving the following equation:

$$G(K^*) = E(w_s) - w_k$$

The difference between the observed total capacity, $Z_{i,t}$, and $K^*_{i,t}$ is the optimal demand for aircraft lease by carrier $I$ in year $t$.

As an illustration, we applied the above procedure to derive the optimal demand for aircraft leasing for the 23 major airlines in 1993. The results are presented in Table 4. It is shown that when the cost premium defined as $[E(w_s) - w_k] / w_k$ is at 5%, the optimal demand for operating lease of aircraft would be about 66% of the existing total fleet for the 23 major airlines. The demand for lease decreases as the premium increases. When premium is at 30%, the demand for lease would be about 40% of the total fleet. This reveals that the flexibility of operating lease is highly valuable to the airlines. In 1993, the actual share of leased aircraft, including both operating lease and capital lease, for the 23 airlines was 45.7% of their total fleet. Since long-term capital lease accounted for about 20% of total lease, the actual share of aircraft under operating lease would be around 37%. Thus, it appears that there is still potential for the growth of the demand for operating lease.

Table 4 also lists the breakdown of total demand for operating lease by the 23 major airlines by the regions. It shows that the North American major carriers account for about two thirds of the demand in the leasing market. As the leasing premium is low, the European and Asian and Oceania major carriers have about the same demand; however, as the leasing premium increases, Asian and Oceania major carriers demand twice as much as the European carriers do.

The results of Table 4 are based on the assumption that all of the major carriers face the same stochastic distribution of traffic growth. This assumption may be unrealistic given that there

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are substantial differences in growth rates experienced in the different regions of the world in the past. As a further illustration, we divide our data sample into three major regions. Based on the sample statistics of the major carriers in each of the regions, we assume

$$Y_{i,t} = Y_{i,t-1} \ (1+\tau), \quad \tau \sim N(\mu, \sigma)$$

where $\mu = .109$, $\sigma = .164$ for North american major carriers; $\mu = .072$, $\sigma = .102$ for European major carriers, and $\mu = .102$, $\sigma = .083$ for Asian and Oceania major carriers. The same procedure to derive firm-specific demand for operating lease is applied again to each of the 23 major carriers and the aggregate results are reported in Table 5. The results are quite similar to those reported in Table 4. The basic pattern of regional demands in Table 4 remains true in Table 5 that the North american major carriers contribute about two thirds of the total demand and the Asian and Oceania major carriers contribute more relative to the European major carriers as leasing premium increases.

The results in Tables 4 and 5 also illustrated the risks to the leasing companies since the lease premiums seem to be quite sensitive to the swings in demand. In view of this, although the industry has good reason to be optimistic about future growth in aircraft lease, there is considerable uncertainties regarding the profitability to the lessors. During the last recession, many leasing companies failed and the leasing industry is still undergoing consolidation as the airline industry has recovered. The empirical methodology illustrated in this section would also be useful to the leasing companies to forecast demand on the aircraft lease.

## 4 SUMMARY

The airline industry all over the world has been increasingly relying on aircraft lease. While previous researchers mostly focused on financial aspects of the leasing, this paper emphasized the

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operational effects of aircraft leasing. It is shown that short-term operating lease provided a vehicle for risk shifting or risk sharing between the airlines and the leasing companies. Operating lease of the aircraft gives the airlines flexibility in capacity management when demand for air transportation service is uncertain and cyclical. As the demand for air service increases, the airlines will be able to quickly expand capacity through aircraft leasing. However, if the demand takes a downturn, the leasing companies which supply the aircraft will suffer from excess capacity. Leasing companies compensate this risk by charging a premium on operating leases. Thus, the airlines are facing a trade-off between flexibility of capacity and higher costs.

This paper developed a model for the airlines to determine their optimal mix of leased and owned capacity. Empirical results based on the data from 23 major airlines in the world suggested that the optimal demand by these airlines would range between 40 to 60 percent of their total fleet, for the reasonable range of premiums of operating lease. To the leasing companies, this indicated huge potential of the market given strong forecast for the growth of air transportation in the next decade. However, the extent of the risks in this market should not be underestimated. The empirical results revealed the sensitivity of the profitability of the aircraft leasing to the swings in the demand. Therefore, the leasing companies should also be cautious in the management of their inventory. The approach illustrated in this paper is also useful to the leasing companies to forecast demand for operating lease of the aircraft and to assess the extent of risks in the market, and thus to have a better management of the supply side of the market.

**Table 1**     Sample of Carriers Used in the Study

North America

| American | 86 - 93 | United | 86 - 93 |
| Continental | 86 - 93 | US Air | 86 - 93 |
| Delta | 86 - 93 | Air Canada | 86 - 93 |
| Northwest | 86 - 93 | CAI | 86 - 93 |

Europe

| Air France | 86 - 93 | KLM | 86 - 92 |
| Alitalia | 86 - 93 | Lufthansa | 86 - 93 |
| British Airway | 86 - 93 | SAS | 86 - 93 |
| Iberia | 86 - 93 | Swiss Air | 86 - 92 |

Asia and Oceania

| ANA | 88 - 93 | Qantas | 86 - 93 |
| Cathay Pacific | 88 - 93 | SIA | 86 - 93 |
| JAL | 86 - 93 | Thai | 86 - 93 |
| KAL | 86 - 93 | | |

**Table 2** Descriptive Statistics of Key Variables in the Sample

| Variable | Mean | Minimum | Maximum |
|---|---|---|---|
| Total Revenue ($million) | 4730 | 794 | 14737 |
| Total Cost ($million) | 4817 | 823 | 14589 |
| Variable Cost ($million) | 4301 | 714 | 13028 |
| Ave. Wage ($thousand) | 44.428 | 8.436 | 107.46 |
| Fuel Price ($/gal.) | 0.74 | 0.51 | 1.55 |
| Output (index) | 1.296 | 0.295 | 4.361 |
| Ave. Load (%) | 67 | 56 | 79 |
| Ave. Stage length (km) | 1608 | 657 | 4371 |

Note: $'s are in US dollar or equivalent.

**Table 3** Estimated Coefficients of Translog Variable Cost Function

| Variable | Coef. | S.E. | Variable | Coef. | S.E. |
|---|---|---|---|---|---|
| Log Likelihood Function | 1367.525 | | | | |
| A0 | 8.2910 | 0.0296 | LD | -0.1113 | 0.0238 |
| Y | 0.5861 | 0.0653 | LS | -0.0811 | 0.0107 |
| D | 0.2663 | 0.0627 | FY | 0.0024 | 0.0125 |
| S | -0.3157 | 0.0335 | FD | 0.0789 | 0.0129 |
| L | 0.3121 | 0.0046 | FS | 0.0086 | 0.0055 |
| F | 0.1460 | 0.0023 | KY | 1.2671 | 0.2150 |
| K | 0.2243 | 0.0581 | KD | -1.0483 | 0.2042 |
| YY | -1.4307 | 0.2708 | KS | 0.1689 | 0.1010 |
| DD | -1.1350 | 0.2068 | Europe | -0.0677 | 0.0238 |
| SS | 0.1892 | 0.0626 | Asia | 0.0243 | 0.0279 |
| YD | 1.2381 | 0.2156 | T87 | -0.0653 | 0.0210 |
| YS | -0.3457 | 0.1299 | T88 | -0.0878 | 0.0227 |
| DS | 0.1819 | 0.1009 | T89 | -0.0863 | 0.0246 |
| LL | 0.1556 | 0.0238 | T90 | -0.1021 | 0.0251 |
| FF | 0.0884 | 0.0054 | T91 | -0.1419 | 0.0249 |
| KK | -1.0989 | 0.2041 | T92 | -0.1689 | 0.0261 |
| LF | -0.0409 | 0.0065 | T93 | -0.1978 | 0.0251 |
| LK | -0.0583 | 0.0238 | eta | 0.0525 | 0.0206 |
| FK | 0.0226 | 0.0114 | e0 | 0.0486 | 0.0530 |
| LY | 0.0543 | 0.0244 | e1 | -0.0140 | 0.0583 |

Variables are as follows: Y is output, L is labour price, F is fuel price, K is capacity, D is load factor, and S is stage length. Labour price and fuel price are normalized by materials price.

**Table 4** Optimal Demand for Aircraft Lease:  Homogeneous forecast of traffic growth

| Cost premium of lease | | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|---|
| Share of lease | (%) | 66.4 | 60.2 | 55.7 | 53.9 | 50.1 | 40.4 |

Demand for lease contributed by the region: (Out of 100 %)

| | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|
| North America | 61.5 | 65.1 | 68.2 | 68.2 | 70.8 | 67.5 |
| Europe | 20.2 | 15.4 | 11.3 | 11.2 | 7.6 | 9.2 |
| Asia and Oceania | 18.3 | 19.5 | 20.5 | 20.6 | 21.6 | 23.3 |

Estimation based on 1993 data.

Cost premium of lease is defined as  $[E(w_s) - w_k] / w_k$.

**Table 5** Optimal Demand for Aircraft Lease: Differential forecast of traffic growth

| Cost premium of lease | | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|---|
| Share of lease | (%) | 66.6 | 63.2 | 55.5 | 53.6 | 44.2 | 40.1 |
| Demand for lease contributed by the region: (Out of 100 %) | | | | | | | |
| North America | | 62.1 | 62.4 | 68.3 | 68.0 | 67.1 | 67.4 |
| Europe | | 20.2 | 19.5 | 11.5 | 11.5 | 8.7 | 9.4 |
| Asia and Oceania | | 17.7 | 18.1 | 20.2 | 20.5 | 24.2 | 23.2 |

Estimation based on 1993 data.

Cost premium of lease is defined as $[E(w_s) - w_k] / w_k$.

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# AIRCRAFT-LEASING INDUSTRY AND SOCIAL WELFARE

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## Abstract

Aircraft leasing has become an increasingly important tool for airline financing. This paper considers the effect of the aircraft-leasing market on the efficiency of the airline industry. Since the aircraft-leasing companies represent an extra layer between aircraft users and aircraft manufacturers, the leasing market adds to the costs of aircraft financing. This paper shows that the aircraft-leasing market serves a valuable social function by improving allocative efficiency of the airlines. The leasing market allows the airlines opportunity to adjust capacity so that the shadow value of capacity can be aligned with the cost of capacity. This is difficult to achieve without the leasing market due to the substantial delivery lag with the aircraft manufacturers. As a result, use of aircraft leasing may increase the expected profits of the airlines even though the airlines are paying higher capacity costs.

The paper also points out that the existence of the aircraft-leasing market may change the aggregate demand for aircraft by the airlines. Specifically, if the shadow value of capacity is nonlinear in capacity, then the aggregate of the optimal capacity of all the airlines in the absence of leasing market differs from the aggregate of the optimal capacity of all the leasing companies supplying to the airlines. This implies that simply aggregating airlines' traffic forecast could lead to erroneous order decision or production plan by the leasing companies or the aircraft manufacturers.

Key Words: Airline financing, Aircraft leasing, Shadow value, Allocative efficiency

## I. Introduction

The aircraft-leasing industry has been expanding at a remarkable pace and, as a result, the lease of aircraft has become an increasingly important tool for the airline industry. According to recent estimates, approximately one-half of the world's aircraft fleet is operating under some kind of lease (Avmark, 1996). Within the lease option, there is an increasing trend in favour of short-term operating lease (Gritta *et al*, 1994). This paper considers the social value of the growing aircraft-leasing industry. The paper attempts to analyze the social benefits as well as social costs given rise by the leasing industry which serves as a financial intermediary between aircraft manufacturers and airlines.

The benefits of leasing were traditionally viewed as financial. As operating lease is not capitalized, air carriers can substantially lower their debt/equity ratio on their balance sheet if they finance their aircraft fleet by leasing rather than by traditional debt. This is commonly referred to as "off-balance-sheet" financing. Another well-known financial benefit is that leasing separates the ownership of an aircraft from the user of the aircraft. Therefore, it is the lenders (lessors) who own the aircraft while the airlines (lessees) operate the aircraft. This separation of ownership enables valuable depreciation allowances to be used more effectively by the lessors for tax purposes.

It may be argued that the effects of off-balance-sheet financing is largely cosmetic because financial analysts would not be fooled when it is publicly known that an airline has

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taken up a substantial lease obligation. Indeed, some researchers demonstrated that lease and debt are substitutes as it would under efficient financial markets (Bayliss and Diltz, 1986; Marston and Harris, 1988). Therefore, leasing as a source of off-balance-sheet financing does not appear to be able to significantly increase a firm's debt capacity. Furthermore, with increasingly stringent accounting and tax rules, the tax effects of leasing are also limited. Now, the major attractions of operating lease of aircraft are viewed as more operational than financial in nature. First, while the aircraft manufacturers currently have substantial order backlogs, major aircraft leasing companies have inventories for immediate delivery. Hence, airlines desiring a quick expansion need not wait for the production backlogs. Second, short-term operating lease provides the flexibility to the airlines so that airlines can manage fleet size and composition as closely as possible, expanding and contracting to match demand.

No doubt, the aircraft-leasing companies are in the business for profits. They purchase aircraft from the manufacturers with means of long-term financing, and then lease the aircraft to the airlines. Therefore, the expected revenues from operating lease must not only cover the long-term financing costs of the aircraft, but also provide the leasing company with a profit. This constitutes an extra cost to the airlines. The extra cost may be viewed as the cost of intermediation since the companies in the leasing industry act as the financial intermediary between the aircraft manufacturers and the airlines.

In this paper, we show that an aircraft-leasing market can improve allocative efficiency of the airlines and result in net social gains if the improvement in efficiency outweights the cost of imtermediation. It is well known that there is a substantial lag in aircraft delivery. As

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a result, airlines anticipating traffic growth and wishing to expand capacity must place orders of aircraft well in advance to the aircraft manufacturers. Once the aircraft are delivered, however, the airlines may find that the anticipated traffic growth has not materialized, resulting in excess capacity; or, equally likely, the realized traffic growth has exceeded the anticipation, resulting in capacity shortage.

In sum, airlines rarely find themselves having just the right amount of capacity by the time the aircraft ordered earlier are delivered. This being the case, the potential for efficiency gains exists because typically airlines are operating with different degrees of excess or under capacity. For instance, a global economic recession may affect certain regions before spreading to other regions. Hence, the airlines operating in the former regions may have significant excess capacity whereas the airlines operating in the latter regions may have less excess capacity or even have capacity shortage. In other words, the marginal value, or the shadow value, of capacity is lower for the airlines operating in certain regions than for the airlines operating in some other regions. It follows that the allocation of capacity among the airlines in this case is not efficient. (Many empirical studies on airlines indicated that the utilization of capacity is one of the important factors determining productive efficiency of the airlines. See, for example, Caves *et al*, 1984; Good and Rhodes, 1991; Good *et al*, 1993; Oum and Yu, 1995; Oum and Zhang, 1991; and Windle, 1991, among others.)

With an active leasing market, the airlines need not order capacity well in advance. The use of short-term operating lease affords the airlines with the flexibility to change aircraft fleet as demand for air transport changes. Given the total stock of aircraft, therefore, the

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leasing market helps to achieve a more efficient allocation of capacity among the airlines. During a recession, the leasing price of aircraft will drop so that the airlines which are less affected, or as yet unaffected, by the recession are encouraged to take more capacity. Similarly, during a recovery, leasing price will increase so that the airlines with less capacity shortage will not compete for capacity with the airlines facing severe capacity shortage. Thus, the function of the aircraft-leasing market makes the shadow value of aircraft of different airlines closer to the leasing price thereby resulting in a more efficient allocation of capacity among the airlines.

## II. Model

We first present a general model on the demand for aircraft by the airlines. We consider two situations. In the first situation, there is no aircraft-leasing market and the airlines must order aircraft directly from the manufacturers. In the second situation, there is a leasing market for aircraft and consequently the airlines can order aircraft from the inventory of the leasing companies.

### 2.1 Demand for aircraft without a leasing market

Suppose there are $N$ airlines. When there is no aircraft-leasing market, the airlines must order aircraft directly from the manufacturers. Let the profit function of the airlines be

$$\pi_i(K_i, \theta_i) = R_i(K_i, \theta_i) - w_k K_i, \quad i = 1, \dots, N \tag{1}$$

where $K_i$ is the capacity in aircraft and $R_i$ is the net revenue (revenue net of variable costs) of the $i$th airline, and $\theta_i$ is a random variable representing the state of nature facing the airline. $w_k$ is the unit fixed cost of the capacity which is a constant for all the airlines.

Due to a delivery lag, the airlines should order aircraft before the state of nature is revealed. Hence, the airlines must determine the capacity based on their expected profits, i.e.

$$\max_{K_i} E[\pi_i(K_i, \theta_i)]$$

This leads to the following first-order condition:

$$E \frac{\partial R_i}{\partial K_i} = w_k \tag{2}$$

The above equation implicitly determines the optimal capacity, $K_i$, for the $i$th airline. The aggregate demand for aircraft by all the airlines is then

$$K = \sum K_i \tag{3}$$

## 2.2 Demand for aircraft with a leasing market

With an active aircraft-leasing market, the airlines do not need to order aircraft in advance

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from the manufacturers. Instead, the airlines can lease aircraft from the leasing companies. In this situation, the capacity of each airline may be determined after the state of nature is revealed. Hence, the optimality condition for the airlines are

$$\frac{\partial R_i}{\partial K_i} = w_s, \quad \forall i \tag{4}$$

where $w_s$ is the unit cost of leased capacity prevalent in the leasing market which depends on the realized states of nature. Let $\tilde{K}_i(w_s)$ denote the solution to the above equation and let

$K$ denote the total capacity in the inventory of the leasing companies. Then, after the state of nature is revealed, the equilibrium in the leasing market requires that

$$\sum \tilde{K}_i(w_s) = K \tag{5}$$

which determines the unit price of capacity as a function of total inventory and the state of nature, i.e., $w_s = w_s(K, \theta)$.

For the leasing companies, the inventory of the aircraft must be ordered in advance from the manufacturers. Assume that the total inventory ordered by the leasing companies will yield the following expected return:

$$E[w_s(K, \theta)] = w_k + \mu \tag{6}$$

where $\mu$ is the expected premium earned by the leasing companies. Solving equation (6) gives the total capacity, $K$, ordered by the leasing companies which will be available to the airlines

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as the state of nature is revealed.

## III. Simulation Analysis

The equilibrium conditions discussed above such as equations (2), (3), (5) and (6) involve implicit functions which are difficult to analyze. In what follows, we carry out some simple simulation analysis to highlight the social values of the aircraft-leasing market.

For simplicity, we first make the following assumption.

(A1) The net revenue is quadratic in capacity:

$$R_i(K_i, \theta_i) = a\theta_i K_i - \frac{b}{2}K_i^2, \quad \forall i$$

such that the shadow value of the capacity is linear in $K$ and in $\theta$:

$$\frac{\partial R_i}{\partial K_i} = a\theta_i - bK_i$$

with $a > w_k + \mu$ and $b > 0$.

In essence, assumption (A1) states that the airlines are operating with the same technology (the coefficients $a$ and $b$ are constant across the airlines) but are facing different passenger demands ($\theta$ differs across the airlines). The latter may be caused by different

geographic regions and/or different regulatory environment in which the airlines are operating. Without loss of generality, we further assume that the random variables, $\theta_i$ are normalized such that

$$E(\theta_i) = 1, \quad \forall i$$

Without a leasing market, condition (2) gives the optimal capacity for each airline:

$$K_i = \frac{a - w_k}{b}, \quad \forall i \tag{7}$$

The aggregate demand is then

$$K = \sum K_i = \frac{N}{b}(a - w_k) \tag{8}$$

With an active leasing market, however, the demand for capacity by each airline is conditional on the leasing price, which can be derived from (4) as

$$\tilde{K}_i = \frac{a\theta_i - w_s}{b}, \quad \forall i \tag{9}$$

The tilde indicates that $K_i$ depends on the state of nature. Let $K$ be the total inventory of the leasing companies. Then,

$$\sum \tilde{K}_i = K$$

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Substituting and solving for $w_s$, we can derive the equilibrium leasing price as

$$w_s = (a\sum \theta_i - bK)/N \tag{10}$$

Taking expectation of $w_s$ and using (6) gives

$$a - \frac{b}{N}K = w_k + \mu$$

which leads to the following total demand for inventory by the leasing companies:

$$K = \frac{N}{b}[a - (w_k + \mu)] \tag{11}$$

Comparing (11) with (8), we have the following conclusion.

**Proposition 1.** Under assumption (A1), the aggregate demand for aircraft is smaller when there is a leasing market than when there is no leasing market.

The intuition of this result is clear. The leasing companies act as market intermediaries. The premium earned by the leasing companies is in essence the cost of intermediation, which raises the user cost of capital to the airlines and thereby reduces the aggregate demand for capacity.

So far we have implicitly assumed that if there is an active leasing market, all airlines will use this market and will stop ordering aircraft directly from the manufacturers. Given the

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existence of the leasing premium in the price of leased aircraft, a question naturally arises: Are the airlines rational to depend on the leasing market for their capacity? To this question, we have the following results.

**Proposition 2.** Under assumption (A1), if the leasing premium $\mu$ is sufficiently small, the expected profits of each airline are higher when all aircraft are leased from the leasing companies than when all aircraft are directly ordered from the manufacturers.

Proof: If all aircraft are directly ordered from the manufacturers, assumption (A1) gives

$$E[\pi_i|K_i] = E[a\theta_iK_i - \frac{b}{2}K_i^2 - w_kK_i]$$

where conditional expectation indicates that capacity $K_i$ is determined before $\theta_i$ is realized. Substituting using (7) and taking expectation gives

$$E[\pi_i|K_i] = \frac{(a-w_k)^2}{2b} \tag{12}$$

When all aircraft are leased from the leasing companies, however,

$$E[\pi_i] = E[a\theta_i\tilde{K}_i - \frac{b}{2}\tilde{K}_i^2 - w_s\tilde{K}_i]$$

where the tilde indicates that $\tilde{K}_i$ (and $w_s$) depends on $\theta_i$. Using (9), (10) and (11), we get

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$$E[\pi_i] = \frac{[a-(w_k+\mu)]^2}{2b} + \frac{a^2}{2bN^2}E\{[\sum_j (\theta_i-\theta_j)]^2\}, \quad \forall i \qquad (13)$$

Since

$$E\{[\sum_j (\theta_i-\theta_j)]^2\} > 0,$$

for $\mu$ sufficiently small,

$$E[a\theta_i\tilde{K}_i - \frac{b}{2}\tilde{K}_i^2 - w_i\tilde{K}_i] > \frac{(a-w_k)^2}{2b}$$

i.e.

$$E_{\theta,\tilde{K}_i}[\pi_i] > E_\theta[\pi_i|K_i]$$

QED.

The intuition of this result may be explained as follows. When capacity is ordered from the manufacturers, the cost of capacity, $w_k$, is fixed. The shadow value of the capacity of each airline, however, depends on the state of nature facing each airline and therefore varies across airlines. Hence, after the state of nature is revealed, each airline is likely to find that the shadow value of its capacity does not equal the cost of the capacity. In other words, since the airlines make the capacity decision before the state of nature is revealed, the allocation of

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capacity among the airlines is likely to be *ex post* inefficient. When there is an aircraft-leasing market, however, the airlines can order capacity after the state of nature is revealed. In this case, although the equilibrium leasing-price varies with the realization of the state of nature, the airlines will always order capacity to the extent that the shadow value of the capacity of each airline equals the price of the capacity. Therefore, the allocation of capacity across all airlines is always efficient *ex post*. If the premium charged by the leasing companies is small relative to the improvement in efficiency of capacity allocation, the existence of an active leasing market will offer the airlines with higher expected profits. As a result, the airlines will choose to lease aircraft rather than to order aircraft directly from the manufacturers.

From the analysis leading to proposition 1, we can see that if the leasing premium is negligible, the aggregate demand for aircraft is the same whether the aircraft are ordered by the leasing companies or directly by the airlines. Now we show that this is true only when the shadow value is linear in capacity. For illustration, we replace assumption (A1) by the following alternative:

(A2) The shadow value of capacity is

$$\frac{\partial R_i}{\partial K_i} = a\theta_i - bK_i^m, \quad \forall i$$

with $a > w_k + \mu$, $b > 0$, and $m > 0$.

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**Proposition 3.** Let $K$ be the aggregate demand for aircraft when there is no leasing market and $K_l$ be the aggregate demand when there is a leasing market. Under assumption (A2), if the leasing premium is negligible, then

$$K_l > K, \quad \text{if } m < 1,$$

$$K_l < K, \quad \text{if } m > 1.$$

Proof: Without a leasing market, optimality condition of each airline gives

$$E \frac{\partial R_l}{\partial K_l} = w_k$$

Substitute using (A2) and solve for $K_i$:

$$K_i = \left( \frac{a - w_k}{b} \right)^{\frac{1}{m}} \tag{14}$$

Hence, the aggregate demand for capacity is

$$K = N \left( \frac{a - w_k}{b} \right)^{\frac{1}{m}}$$

With a leasing market, the optimality condition for each airline becomes:

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$$\frac{\partial R_i}{\partial K_i} = w_s, \quad \forall i$$

which leads to

$$\tilde{K}_i^m = \frac{a\theta_i - w_s}{b} \tag{15}$$

Taking expectation, noting that $w_s$ depends on the state of nature, yields

$$E(\tilde{K}_i^m) = \frac{a - (w_k + \mu)}{b}$$

By the well-known result that if $f(\,.\,)$ is concave $f[E(x)] > E[f(x)]$, we have

$$[E(\tilde{K}_i)]^m > E(\tilde{K}_i^m), \quad \textit{if } m < 1$$

Hence

$$E(\tilde{K}_i) > \left[\frac{a - (w_k + \mu)}{b}\right]^{\frac{1}{m}}, \quad \textit{if } m < 1$$

and the aggregate demand

$$K_l = \sum \tilde{K}_i = \sum E(\tilde{K}_i) > N\left[\frac{a-(w_k+\mu)}{b}\right]^{\frac{1}{m}}, \quad \text{if } m < 1$$

When the leasing premium $\mu$ is negligible, this gives $K_l > K$.

Similarly, if $m > 1$, $f(x) = x^m$ is convex, and we will have

$$[E(\tilde{K}_i)]^m < E(\tilde{K}_i^m)$$

and so

$$K_l < N\left[\frac{a-(w_k+\mu)}{b}\right]^{\frac{1}{m}}, \quad \text{if } m > 1$$

which gives $K_l < K$ when $\mu$ is negligible. QED.

As for the expected profits, we have the following result.

**Proposition 4.** Under assumption (A2), if the leasing premium is sufficiently small, the expected profits of each airline are higher when all aircraft are leased from the leasing companies than when all aircraft are directly ordered from the manufacturers.

Proof: By assumption (A2), the net revenue function may be obtained as

$$R_i(K_i, \theta_i) = \int_0^{K_i} \frac{\partial R_i}{\partial K_i} dK_i = a\theta_i K_i - \frac{b}{m+1} K_i^{m+1}$$

Without a leasing market, the expected profits of each airline are

$$E[\pi_i | K_i] = E[R(K_i, \theta_i) - w_k K_i]$$

$$= E[(a\theta_i - w_k) K_i - \frac{b}{m+1} K_i^{m+1}]$$

Taking expectation and substituing using (14), we obtain

$$E[\pi_i | K_i] = \frac{m}{m+1} \frac{(a - w_k)^{(m+1)/m}}{b^{1/m}} \tag{16}$$

With the leasing market, the expected profits of each airline become

$$E[\pi_i] = E[(a\theta_i - w_s) \tilde{K}_i - \frac{b}{m+1} \tilde{K}_i^{m+1}]$$

Substituting using (15) gives

$$E[\pi_i] = E[\frac{mb}{m+1} \left( \frac{a\theta_i - w_s}{b} \right)^{(m+1)/m} ]$$

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By assumption, $m > 0$, $f(x) = x^{(m+1)/m}$ is convex in $x$. Thus

$$E[\pi_i] = \frac{mb}{m+1}E\left[\left(\frac{a\theta_i - w_s}{b}\right)^{\frac{m+1}{m}}\right] > \frac{mb}{m+1}\left[E\left(\frac{a\theta_i - w_s}{b}\right)\right]^{\frac{m+1}{m}} = \frac{m}{m+1}\frac{[a-(w_k+\mu)]^{(m+1)/m}}{b^{1/m}}$$

Comparing with (16), we see that, for $\mu$ sufficiently small,

$$E[\pi_i] > E[\pi_i | K_i]$$

QED.

The results of proposition 4 show that, under the specification of (A2), the operation of the leasing market enhances the expected profits of airlines whether the shadow value is concave or convex in capacity. Furthermore, proposition 3 reveals that the existence of the leasing market may change the total order-bill received by the aircraft manufacturers. This has some interesting implications. Suppose, for instance, the shadow value is convex in capacity ($m > 1$). Without a leasing market, the airlines will order aircraft for future delivery based on estimated traffic growth facing each airline. Hence, the aircraft manufacturers can forecast demand for aircraft using the airlines' estimates. With a leasing market, however, the aircraft manufacturers will overestimate the demand for aircraft if the estimation is based on the aggregation of airlines' forecast of traffic growth. The leasing companies face a similar problem. If the leasing companies estimate the demand for aircraft by simply aggregating the

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estimated traffic growth by the airlines, the leasing companies may end up suffering from excess capacity and may fail to earn the expected premium.

## IV. Conclusion

For more than a decade, we have seen a rapid expansion of the aircraft-leasing market and an increasing reliance on aircraft leasing by the airlines all over the world. This active leasing market has given the airlines flexibility in capacity management and thereby offered a vehicle for risk-sharing between the airlines and the leasing companies. To the airlines the flexibility comes at a cost because the average price of short-term lease is typically higher than the long-term cost of capital. On the whole, the aircraft-leasing companies represent an extra layer between the aircraft users and the aircraft manufacturers. Therefore, the operation of the leasing market adds to the aggregate costs of capacity of the airlines.

This paper shows that the aircraft-leasing market also serves a valuable social function, namely, to improve the allocative efficiency of the airlines. Through the operation of the leasing market, the airlines may adjust capacity in short term so that the shadow value of capacity is aligned with the cost of capacity. This is difficult to achieve without the leasing market due to the substantial delivery lag with the aircraft manufacturers. As a result, use of aircraft leasing may increase the expected profits of the airlines eventhough the airlines are paying higher capacity costs.

The paper also points out that the existence of the aircraft-leasing market may change

the aggregate demand for aircraft by the airlines. Specifically, if the shadow value of capacity is nonlinear in capacity, then the aggregate of the optimal capacity of all the airlines without using the leasing market differs from the aggregate of the optimal capacity of all the leasing companies supplying to the airlines. This implies that simply aggregating airlines' traffic forecast could lead to erroneous order decision or production plan by the leasing companies or the aircraft manufacturers.

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# THE DEVELOPMENT OF PERFORMANCE INDICATORS FOR AIRPORTS:

# A MANAGEMENT PERSPECTIVE

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## 0. INTRODUCTION

The literature in general management has argued that financial performance indicators need to be complemented by non financial performance indicators. Thus in accounting it has been argued that researchers should attempt to develop non-financial measures of manufacturing performance, such as productivity, quality, and inventory costs (Kaplan, 1983). Later following this theme, Kaplan and Norton (1992) developed the balanced score card which included not only financial measures but also indicators from the customer, internal business process and innovation perspective.

This paper will examine the measurement of airport performance from three general management perspectives: the financial perspective, the marketing perspective and the operational perspective.

## 1. THE FINANCIAL PERSPECTIVE

Two aspects of the financial perspective have been well researched:

- measures for management accounting and internal reporting

- measures for financial analysis

### 1.1. Measures from management accounting and reporting

The most obvious indicators of financial performance are the amount totals in different accounts as shown in both the operating statement and the balance sheet. However, more sophisticated performance indicators have been recently developed in the literature on airports according to the purpose at hand, i.e., for financial control and budgeting (Wells, 1986), for decision making (Ashford and Moore, 1992) and for assessing performance over time of an organisation (ICAO, 1991).

For financial control and budgeting Wells (1986) applied traditional financial control and accounting techniques for the particular management of airport budgets.

To facilitate decision making a financial management information system will provide managers with a variety of indicators, according to the nature of the decision to be taken. Strategic indicators are required for policies with medium to long-term effects whereas tactical indicators assist in decision making for the short and medium term. Day-to-day indicators advise the manager of the current status of the enterprise for short and very-short-term courses of action. Target indicators are agreed at national, state or local government level, as appropriate, in the case of a public airport (Ashford and Moore, 1992). These indicators are detailed in table 1. It should be noted that non-financial performance criteria, e.g., level of service criteria have been suggested.

**Table 1. Airport financial performance indicators (Ashford and Moore, 1992)**

| Strategic indicators | Tactical indicators |
|---|---|
| Return on capital investment<br><br>Pay back period<br><br>Self financing ratio<br><br>Current assets / liabilities<br><br>Debtors ratio<br><br>Creditors ratio | Income per passenger or work load unit (WLU)<br><br>Cost per passenger or work-load unit<br><br>Income per unit or facility or throughput<br><br>(for example, income per square meter or square foot, income per available parking space)<br><br>Cost per unit of facility or throughput<br><br>Gross profit on sales<br><br>Rate of return on sales<br><br>Percentage of concessionary sales<br><br>Overtime hours/normal hours ratio |

source: Ashford and Moore, 1992.

| Day-to-day indicators | Target indicators |
|---|---|
| Cash flows<br><br>Revenue flows<br><br>Expenditure flows<br><br>Actual and budgeted revenues and expenditures<br><br>Outstanding debtors and location of debt<br><br>Outstanding creditors and location of credit | Return on capital<br><br>Cost improvements<br><br>Productivity improvements<br><br>Level of service criteria<br><br>(e.g.: equipment availability, complaints, and compliments) |

source: Ashford and Moore, 1992

In order to analyse change in financial performance over time and to identify areas needing attention, ICAO (1991) suggested the financial performance indicators in Table 2. It was also recognised that operational performance indicators may be equally important.

**Table 2 - Airport financial and economic performance indicators (ICAO ,1991)**

| | |
|---|---|
| Income per passenger | Passengers per employee |
| Expenditure per passenger | Income per employee |
| Trading profit per passenger | Value added per employee |
| Aeronautical income per passenger | Capital expenditure per passenger |
| Non - aeronautical income per passenger | Net assets per employee |

source: ICAO ,1991.

## 1.2. Financial analysis

Performance indicators have been outlined in the literature on financial analysis for internal control (Ashford and Moore, 1992), external control (Civil Aviation Authority, 1991), and investment evaluation (Congressional Budget Office, 1984; Moody's, 1992).

Internal targets have been set as financial ratios for some airports in order to create a more "commercial attitude". For example, Schiphol Airport set the following company financial targets, table 3, (Ashford and Moore, 1992) :

### Table 3 - Schiphol Airport company wide financial targets

| |
|---|
| Cost of capital: 10 percent per annum or less |
| Equity/debt ratio: 1.5 minimum |
| Return on assets: 6 percent |
| Cash flow/interest requirement ratio: 3.0 minimum |

source: Ashford and Moore, 1992.

Financial ratios which are used by government to control privately owned airports (monopoly in that case) are included in table 4.

### Table 4 - Financial Performance Indicators (Civil Aviation Authority, 1991)

| | |
|---|---|
| Revenue | Average capital employed |
| Operating profit | Return of profit on revenue |
| Capital employed | Return on average capital employed |

source: Civil Aviation Authority, Monopoly and Mergers Commission, 1991.

Moreover, the US Congressional Budget Office suggested four indicators for airport investors (Congressional Budget Office, 1984), those are in table 5.

### Table 5 - Indicators for airport investors (Congressional Budget Office, 1984)

$$\text{Operating ratio} = \frac{\text{operating expenses}}{\text{operating revenue}}$$

$$\text{Net take-down ratio} = \frac{\text{total revenue} - \text{operating expenses}}{\text{total revenue}}$$

$$\text{Debt-to-asset ratio} = \frac{\text{gross debt} - \text{bond principal reserves}}{\text{net fixed assets} + \text{working capital}}$$

$$\text{Debt service safety margin} = \frac{\text{total revenues} - \text{operating expenses} - \text{debt service}}{\text{total revenues}}$$

source: Congressional Budget Office, 1984.

In addition, Moody (1992) suggested the performance indicators in table 6:

### Table 6 - Moody's indicators

| Revenue per enplaned passenger | Debt ratio |
|---|---|
| Operating ratio | Debt service coverage |
| Net take-down | Aircraft parking fees/ 1000 lb. |
| Debt per enplaned passenger | Passenger Terminal Rent/Acre/year |
| Debt service safety margin | |

source: Moody (1992)

## 2. THE MARKETING PERSPECTIVE

The marketing perspective on measurement of airport success focuses on passenger satisfaction and evaluates

- passenger satisfaction with airport terminal buildings

- passenger satisfaction with airport access.

### 2.1. Evaluation of passenger satisfaction in airport terminal buildings

A literature search uncovered various performance indicators for evaluating passenger satisfaction. A perception response model related passenger perception of the level of service provided to the time spent in various service processes (Mumayiz and Ashford, 1986). Later, Mumayiz's (1991) derived threshold values for passenger perception of service from attitudinal surveys conducted at airports at regular intervals. Passenger's perception related to delays, queues, crowding, congestion.

Omer and Khan's (1990) approach was based on economic theory rather than marketing theory. They developed a theoretical model based on utility for measuring the level of service provided in passenger terminal building. The level of service is described as user-perceived operating conditions (e.g. the degree of congestion) at various processors, reservoirs, and links. Their approach has not been implemented. Muller and Gosling's (1991) study of the relationship between waiting time, crowding and the resulting perceived quality of service was based on psychological theories of perceptual scaling and categorical judgment. This method was applied to a passenger survey at San-Francisco International Airport. Ndoh and Ashford (1993) incorporated passengers' service perception as expressed in natural language. Their approach was based on the use of linguistic variables and fuzzy set theory. These linguistic variables were

(1) at holding facilities: crowding, comfort, visual interest, waiting time;

(2) at circulatory facilities: walking distance, directness, signing, ease of transiting.

In fact each of these variables can be considered as a performance indicator of passenger level of satisfaction.

The above studies defined variables for the perception of the quality of service according to one stakeholder, the passenger. Different variables should be used however according to the point of view of particular customers: passengers, airport operators, airlines, concessionaire local government and Federal government. These `customers' are airport stakeholders with

conflicting interests: therefore the variables will differ according to their individual interests and priorities (Lemer, 1990, 1992).

Table 7 summarises the above methods and performance indicators used in evaluating passenger satisfaction.

### Table 7 - Methods and Performance Indicators used in the literature for evaluating passenger satisfaction in a terminal

| Authors | Methods | Performance Indicators |
|---|---|---|
| Ndoh and Ashford (1993) | Modeling the linguistic variables provided by the users via fuzzy sets and linguistic value computation | • At holding facilities<br><br>crowding<br>comfort<br>visual interest<br>waiting time<br><br>• At circulatory facilities<br><br>walking distance<br>directness<br>signing<br>ease of transiting |
| Martel and Seneviratne (1990) | Attitudinal passenger surveys Empirical study conducted on Dorval Airport PTB Montréal | Information<br><br>Waiting time for processing activities<br><br>Availability of seats<br><br>Concessions (i.e., variety and accessibility)<br><br>Internal environment (i.e., aesthetics and climate) |
| Mumayiz and Ashford (1986) | Perception response model | Time spent in various processors |
| Mumayiz (1991) | Derive quantitatively target threshold values for passenger perception of service based on attitudinal surveys conducted at airports at regular intervals<br><br>Measure quality of service at processing facilities of airport terminals based on user's perception and evaluation of service | Delays<br><br>Queues<br><br>Crowding<br><br>Congestion |
| Muller and Gosling (1991) Muller (1987) | Framework based on psychological theories of perceptual scaling and categorical judgement<br><br>Passenger survey at San-Francisco International Airport | Waiting time<br><br>Crowding |

| Ashford (1990) | Obtain by survey a user-perceived level of service | P.I vary according to the type of passenger's activity. |
|---|---|---|
| | Methods and measures to be used to evaluate the level of service of an airport according to the type of passenger's activity | 1. processing<br>2. holding.<br>3. circulation |
| | Design of transport facilities | Technics for evaluating level of service: |
| | | 1. queuing: (a) space provided - (b) time spent in queue |
| | Examples of passenger service standards BAA - IATA - Shipphol airport | 2. holding: (a) space - (b) time |
| | | Area per person available at that facility at a given time |
| U.S Department of Transport - Office of Consumer Affairs - Air Travel Consumer Report - (1990) | | Flight delays<br><br>Mishandled baggage<br><br>Oversales<br><br>Consumer complaints |
| Omer and Kahn (1990) Kahn (1992) | Theoretical model based on utility theory<br><br>Model has not been implemented<br><br>Development of a utility-theoretics methodology for quantifying level of service by taking into account the time and space standards | Existence of a relationship between space/service standards, user perceived value on utility of level of service and cost.<br><br>Trade-offs between the value of the indicators related to level of service and the value of the indicators related to costs. |
| Lemer (1990, 1992) | P. I defined according to the stakeholders conflicting interests<br><br>Passengers<br><br>Airport operators<br><br>Airline viewpoint<br><br>Concessionaires<br><br>Local government<br><br>Federal government | For Passengers:<br><br>compactness (walking distance, level changes)<br><br>delay and waiting times<br><br>service reliability (convenience costs)<br><br>- |

## 2.2. Evaluation of passenger satisfaction for airport access

Airport access focuses on the passenger's journey to the airport. A key aspect of customer satisfaction is the ease with which the passenger gains access to the airport. To construct a passenger perception model of the quality of airport access, Ndoh and Ashford (1993) used mode availability, airport distance, various components of journey time, level of convenience and comfort, and mode reliability. A passenger's perception of airport access will affect his/her perception of the airport's overall level of service.

**Table 8 - Methods and performance indicators for a passenger perception model of the level of service provided for airport access**

| Author | Methods | Performance indicators |
|---|---|---|
| Ndoh and Ashford (1993) | Psychometric techniques (psychometric mathematical models for analysing categorical data rooted in the law of comparative judgment<br><br>Method applied to a case study of access at London Airport. | • Mode availability<br><br>• Airport distance<br><br>• Various components of journey time (waiting, processing, access to mode, mode transfer, in-vehicle)<br><br>• Level of convenience and comfort (ease of use and luggage handling, number of terminal and vehicle transfers, parking availability)<br><br>• Mode reliability to ensure on time performance |

## 3. THE OPERATION PERSPECTIVE

While the above approaches for the design of performance measures are based on customer perception, the operation approach is based on the producer's perception of the quality of service provided (Garvin, 1984).

The literature can be divided according to each operation area of airport service; viz. the airside and the landside. The airside includes the aprons and the runway. The landside includes the airport passenger terminal building and ground access facilities.

### 3.1. Airside

The evaluation of the airside performance is mainly based on the evaluation of capacity. This area is too complex technically to allow its expansion in this paper. The reader may wish to refer to Toldy (1982).

### 3.2. Landside: passenger terminal building and ground access facilities

For passenger terminal buildings, time and space have emerged as the main dimensions recommended for the evaluation of service quality (Johnson and Sellinger, 1983; Muller, 1987). Time is expressed in terms of waiting time and passengers' "dwelling" time within the terminal. Waiting time refers to the time spent in the different airport processes (reservoirs) e.g. check-in, luggage, customs while dwelling time is the time spent in the whole building (Odoni and de Neufville, 1990). Space relates to crowding and is expressed in terms of square metre per passenger. Brink and Madison (1975) added other dimensions: walking distance and passenger orientation (the ability of the passenger to find his/her way easily in the terminal). Passenger orientation is regarded by some as the major functional requirement of passenger terminal buildings (Modak and Patkar, 1984). Comprehensive lists of performance indicators such as safety, security and accessibility to amenities, are included in technical manuals for airport terminal design (Passenger terminal building design manual AK - 62 - 10, IATA 1990).

Table 9 - outlines the different dimensions for evaluating the operational performance of passenger terminal buildings. Each of these dimensions is expressed as a performance indicator.

**Table 9 - Performance indicators for evaluating the performance of the passenger processing system (the terminal area)**

| Authors | Performance indicators |
|---|---|
| Fruin<br><br>(1971) | Ease of flow<br><br>Freedom of movement |
| Brink and Madison<br><br>(1975) | Passenger walking distance<br><br>Processing time<br><br>Congestion<br><br>Waiting time<br><br>Occupancy parameter (crowding) |
| Passenger terminal building design manual AK - 62 - 10 (1978) | • **Operational effectiveness**<br><br>Safety and security<br>Comfort<br>Convenience<br>Flow of traffic<br>Delays<br><br>• **Flexibility**<br><br>Change/growth<br><br>• **Economy**<br><br>Cost and revenue<br>Benefit balance<br><br>• **Passenger convenience / comfort**<br><br>Travel time<br>Walking distance<br>Accessibility to amenities<br>Service convenience<br>Clarity signage<br>Passenger opportunity for communications about orientation and information |
| Modak and Patkar<br><br>(1984) | Passenger orientation |
| Ashford<br><br>(1990) | • **For passenger activity**<br><br>Processing time<br>Queuing time<br>Time spent in queue<br><br>• **For holding areas**<br><br>Space<br>Time |

| IATA<br><br>(1990) | • **Prime criteria** for evaluating the level of service are<br><br>Space available to occupants<br>Time<br><br>• **Additional criteria**<br><br>Comfort<br>Convenience<br>Distance<br><br>• **Factors affecting space required** in relation to occupancy / time<br><br>Passenger behaviour patterns<br>Psychological requirements<br>Passenger comfort |
|---|---|
| Odoni & de Neufville<br><br>(1990) | Passenger dwell time within the terminal |
| Lemer TRB 1199<br><br>(1990) | Waiting time<br><br>Processing time<br><br>Crowding<br><br>Amenities for comfort and convenience<br><br>Delays |

For the evaluation of ground access facilities performance indicators have been developed for parking lots, curbs and roadways (table 10).

### Table 10 - Evaluation of the Level of service of ground access facilities

| Author | Performance Indicators |
|---|---|
| IATA<br><br>(1990) | **Parking lots**<br><br>Availability of parking spaces (probability of a space being available, related to the demand for space)<br><br>Flow/Capacity ratio<br><br>Accessibility<br><br>**Curbs**<br><br>Probability of finding a curb stall given the number of stalls<br><br>Dynamic flow<br><br>Volume of demand.<br><br>**Roadways**<br><br>Traffic volume<br><br>Vehicle speed<br><br>Roadway design |

## 4. CONCLUSION

This paper has examined the development of performance indicators for airport management according to three perspectives: the financial perspective, the marketing perspective and the operation perspective.

The financial literature has revealed indicators for reporting and financial assessment of airports. It has been rightly argued that these financial indicators are not sufficient and should be supplemented by more qualitative indicators.

The marketing literature has focused on the evaluation of passenger satisfaction at airport terminal and airport access. However the passenger is far from being the sole customer of an airport. Other stakeholders (customers) should include the airline, the surrounding community, employees of the different entities working on the airport...The development of performance indicators from a marketing point of view should also include the evaluation of the satisfaction of these various "customers".

The airport operation literature has divided the airport into different areas: airside and landside. Then each of these areas is divided into sub-areas: e.g. reservoir and links in the terminal. The performance indicators developed in that perspective differ from the one developed from a marketing perspective. They are different in the way that for the evaluation of customer satisfaction the important point is the customer's perception of the quality of service provided, while from an operational point of view it is the technical quality which is important. Passenger's perception of waiting time at check-in counters could differ from passenger's actual waiting time at check-in counters.

Further research in the development of performance indicators should aim at developing a balanced score card (Kaplan and Norton, 1992) adapted specifically to airport management.

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# Study about operational effects of the "security check-in" implantation in Brazilian international airports

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# 1 INTRODUCTION

With the growing of the air traffic, the passengers' terminals have been presenting an increase of congestion situations in the departure as in arriving processes. Such congestion can cause delays and queues, affecting the passenger's perception on quality of service offered.

On this aspect the airline should have a concern about the departure process that, how it's administered by its own, contribute strongly to the image of the company to its customers.

Specifically for North American airlines and for some other ones with flights to the United States of America, there is the "security check-in" procedure. This procedure came from the need of these companies to protect their aircraft and their passenger from the international terrorism's growing. This became a demand of FAA (Federal Aviation Administration - USA) for the aircraft destined to the United States of America.

The inclusion of the "security check-in" can influence the operational performance of departure affecting the user's perception in relation to the airline offered. In this group of airlines American Airlines is included.

The verification of the occurrence of deficiencies in the departure components can be done through the comparison among the performance patterns used by the airline and the measured ones. This is done in this work monitoring the process of "security check-in" and "check-in" through the mensuration of important parameters, as time of processing and number of people in queue.

# 2 CONCEPTUAL DEFINITION OF THE PROBLEM

Initially we have to emphasize the passengers' class in study is the economic one. The procedure of "security check-in" has its limits established by the passenger and well-wishers' arrival to the queue to the interviews, and by the passenger's liberation for the check-in counter and by the baggage liberation to the X-Rays' machine.

Passengers and well-wishers arrive to the "security check-in" queue and they stay together until the beginning of a small ribbons corridor, where there just stay the passengers. Then these passengers will be driven to the interview counters, where airline employees proceed the demands of FAA, in a sequence of 7 basic questions trying to detect possible terrorists or carriers of indefinite baggage.

If the passenger doesn't show up any doubt (communication lack or suspicion) it is guided to the "check-in" queue. Otherwise, it is driven to an isolated room where its baggage is opened and inspected through a X-Rays' machine. In both cases, if no problem are observed the baggage receive a stamp indicating that passed by the security check.

After this procedure the passengers are placed in another queue where they will make its "check-in".

After the baggage be dispatched in the check-in they are send to X-Rays' machine, that taking in its failures, shift changes of the operator etc it will process the baggage, that are taken to the aircraft.

## 3 DATA COLLECTION, TREATMENT AND ANALYSIS

An initial data collection was accomplished in the beginning of a great international traffic period on the Brazilian airport scenario and particularly of AISP/GRU. On this month it was chosen the second week to avoid the effects of the beginning and of the end of the month.

In the Table 1 the information collected from American Airlines are presented: the numbers of the flights, the destinies, the aircraft, the frequency of the flights and the foreseen schedules of departure.

Table 1 - Information of the flights.

| Flight | Destiny | Aircraft | Frequency | Time |
|--------|---------|----------|-----------|-------|
| AA006 | Miami | 767-300 | diary | 09:55 |
| AA907 | Assumption | 767-300 | diary | 10:00 |
| AA999 | Montevideo | 767-300 | diary | 10:10 |
| AA950 | New York | 767-300 | diary | 21:45 |
| AA924 | New York | 767-300 | diary | 22:00 |
| AA906 | Miami | 767-300 | diary | 23:00 |
| AA962 | Dallas | 767-300 | diary | 23:15 |

The days of accomplishment of the data collection were Tuesday, Wednesday, Thursday, Friday and Saturday. The period of data collection was defined as being the nocturne for presenting larger movement to the USA.

The collected data were the following ones:
- "security check-in" processing time;
- "check-in" processing time;
- X-Rays' machine processing time;
- number of people in the "security check-in" queue, in intervals of 5 minutes;
- number of passengers in the "check-in" queue, in intervals of 5 minutes;
- arrival instants to the "security check-in" queue.

Data collection were accomplished for the six parameters in subject through takings of time (processing time), counting (number of people in queue) and annotations of the instants of the passengers' arrival.

The data collection was accomplished in three phases, being the first one destined to the taking of processing times, the second one seeking the counting of the number of people in the queue and the third measuring the instants of passengers' arrival.

1st phase – Processing times

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This phase took three collecting a processing type each day. The processing time in a "security check-in" counter was collected in the first day, the processing time X-Rays' machine in the second day and "check-in" processing time in the third day.

2nd phase - Number of people in "security check-in" and in the "check-in" queues

In this phase, accomplished in the fourth day, it was counted the number of people in the queues, with an interval of 5 minutes.

The number of people was counted in the "security check-in" queue, not the amount of passengers, because without an interview it is very difficult to identify the passenger.

3rd phase - Arrival instants

It was measured the arrival instants to the "security check-in" queue of each group of passengers. This phase took place in the fifth day.

To avoid digitizing mistakes of times, common in this type of data collections, an automatic method was used, to the collection as to the transfer of data for a personal computer for posterior treatment. This automatic method developed a program in HP 48GX calculator that took the actual time with the press of a key.

## 3.2 Treatment and analysis

The results obtained in the treatment divide, for each data type, in the following way:
- basic statistics, adherence to distribution of probability and qualitative observations for the processing times and times between arrivals;
- graphs and qualitative observations of the number of people in the queues;
- distribution curves of the arrivals and qualitative observations of the arrival instants.

## 3.2.1 Time of processing and between arrivals

Table 2 presents the results obtained from data collected, treated statistically.

Table 2 - Statistics and distributions.

| Data | Sample | Average (s) | Standard deviation | Distribution |
|---|---|---|---|---|
| Time of processing in the "security check-in" | 120 | 192 | 71.4 | NORMAL(192, 71.1) |
| Time of processing in the "check-in" | 77 | 252 | 105 | 98 + 391 * BETA(0.923, 1.42) |
| Time of processing X-Rays' machine | 195 | 14 | 2.08 | 9 + WEIBULL(5.5, 2.33) |
| Time between arrivals | 272 | 40.7 | 60.8 | -0.001 + WEIBULL(28.5, 0.588) |

The "security check-in" processing time presented was compatible with the international airports' average (180 to 240 seconds). The "check-in" processing time presented a

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resulted inside of the strip of 155 to 300 seconds of international airports, presented by Horonjeff & McKelvey (1994), and it was shown very superior to the 148 seconds obtained in the data collection of 1991 in AISP/GRU (MBA EMPRESARIAL, 1991).

For the X-Rays' machine, a considerable increase of the processing time was observed when the accumulation of the number of bags for loader and of the loaders' grouping generating, unlike the expected, queues before the machine. Operationally there are some interesting aspects in this component. The bags are removed from the conveyor, carried 15 meters by the loaders, processed and taken for the palettes, 5 meters distant of the X-Rays' machine. Besides, the operators of the X-Rays' machine possess shift changes every 20 minutes for not harming its analysis power. Inside of a period of 2 hours it can have flaw in the apparel, needing 1 minute to restart the process. There is a average occurrence of more detailed verifications of 1 bag per hour, demanding 1.5 minutes of the equipment.

### 3.2.2 Number of people in the queues (5 minutes' intervals)

The Figures 1 and 2 present the results of the data treatment of the number of people in the "security check-in" queue and of passengers in the "check-in" queue", respectively.
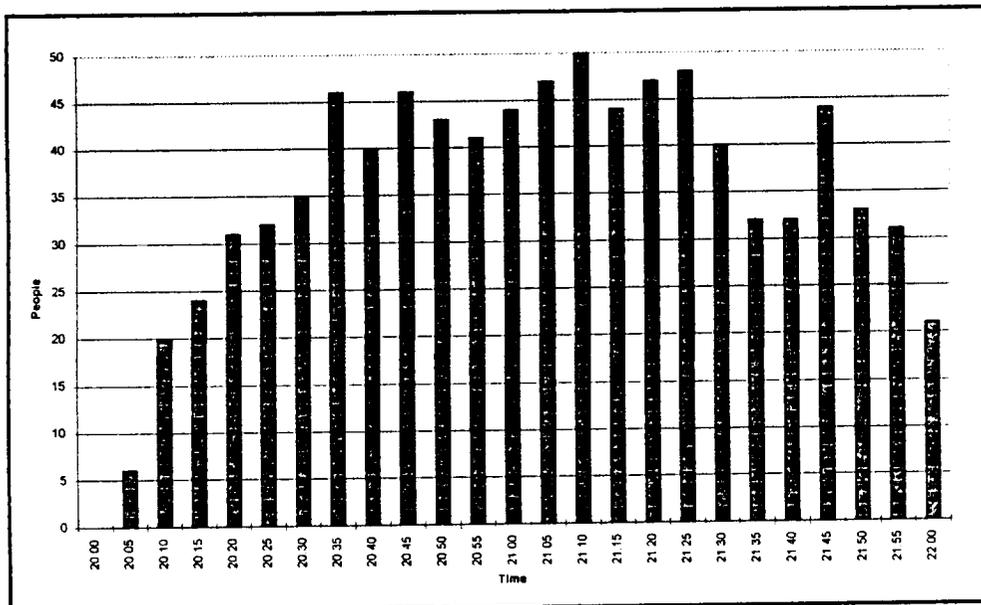


**Figure 1 - Number of people in the "security check-in" queue.**
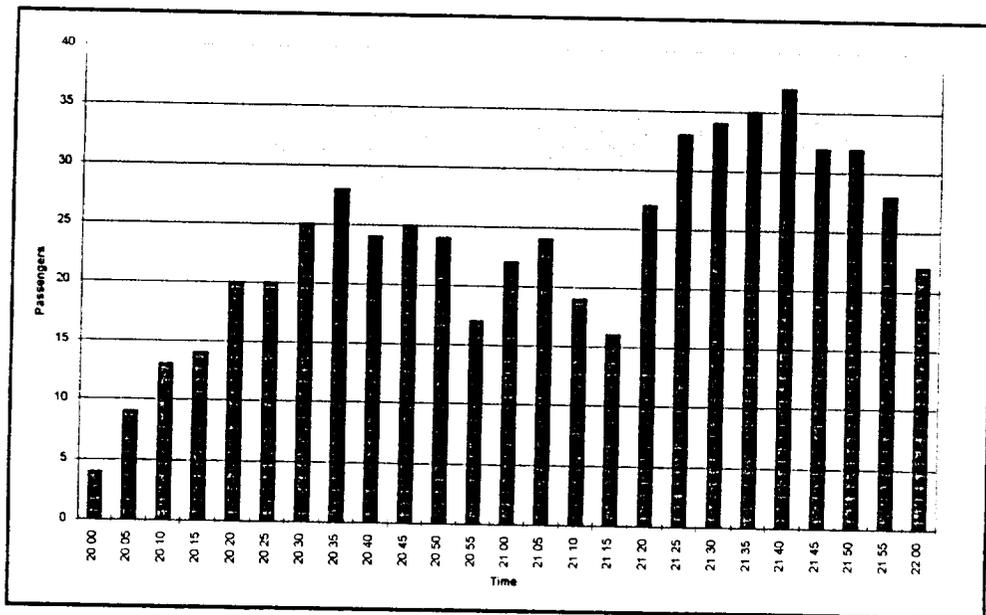
**Figure 2 - Number of passengers in the "check-in" queue.**

Arrival instants
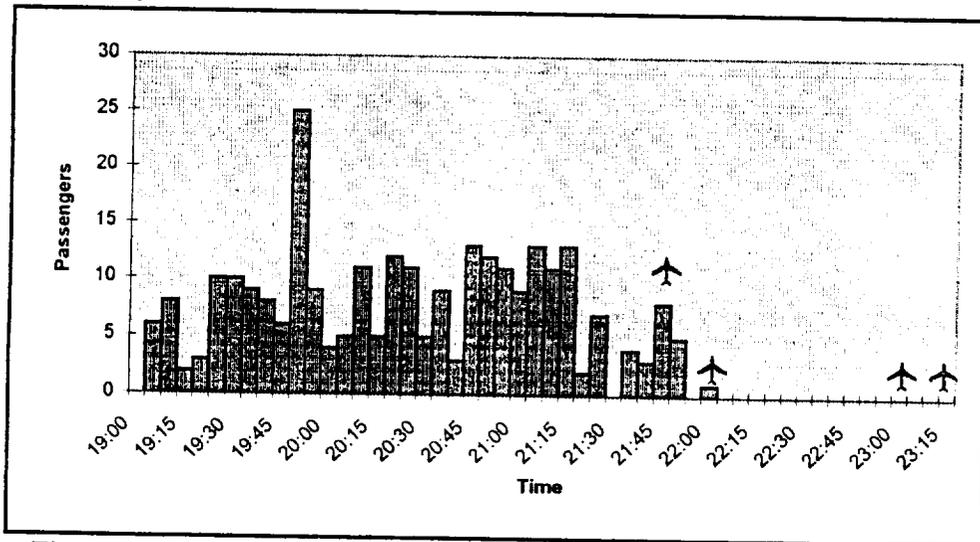


**Figure 3 - Curve of passengers' arrival to the "security check-in" counter.**

The curve of arrival obtained allows to infer that the passengers' antecedence in relation to the foreseen departure schedule is not of 2 hours as in the literature, but around 3 hours.

The peaks in the arrival curve are atypical and they can be explained by great occasional flows that alter the format of the graph. This is perfectly fitted with the existence of periods in that the demand for the air transport is very superior to the average (high season) prevailing tourism traveling passengers.
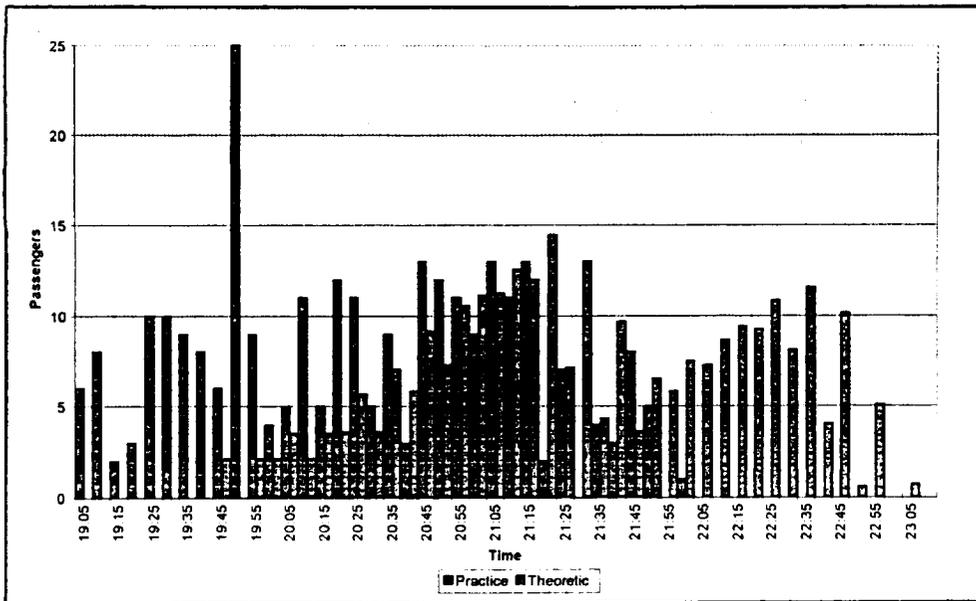
**Figure 4 - Curves of passengers' arrival to the "security check-in" counter compared with the theoretical.**

The theoretical curve of arrival was built with the "ATO arrival curve" (Appendix 1). The final curve resulted of a linear combination of the flight curves pondered by the numbers of passengers departing in each flight. Knowing that the collection of data was just accomplished for the economic class, another pondering factor was adopted through the relationship among the number of passengers and the total of all the flights.
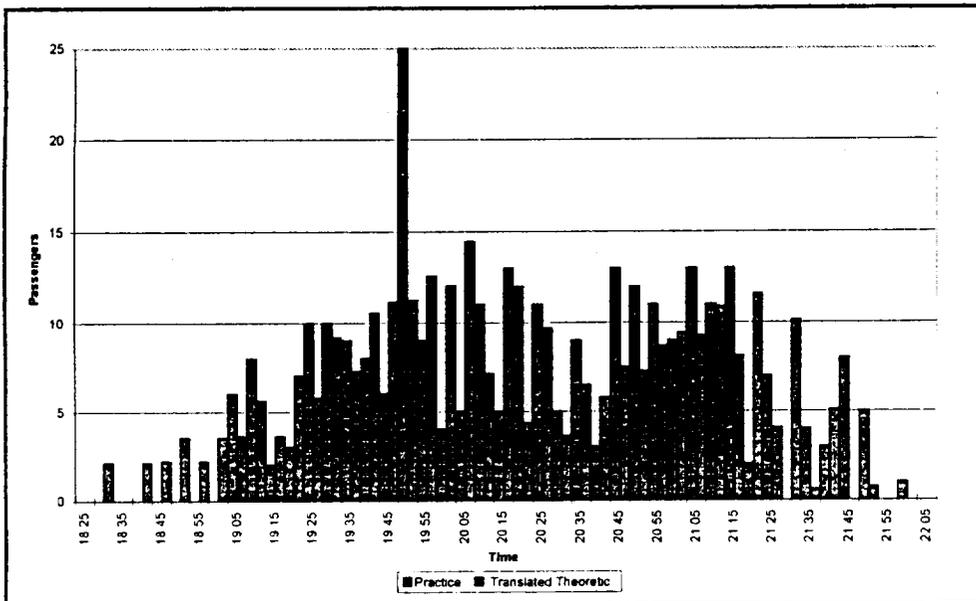


**Figure 5 - Curves of passengers' arrival to the "security check-in" counter compared with the theoretical translated of 1:15 h.**

It was made an analysis of the theoretical curve and it was concluded that a translation of 1h15min is more adapted to have temporary coherence of the data supplied by American Airlines with the obtained empirically.

The observation of this difference makes us believe the use of the theoretical curve as support to program the scheduling and the number of counters doesn't probably supply the operational optimization of the component.

It is interesting to notice that in the translation of the theoretical arrival curve the main characteristic was the alteration of the reference parameter. In the original theoretical curve this parameter was the foreseen schedule of departure of the flight and in the translated, the instant of opening of the "check-in." Actually it is a significant alteration of the characteristics of the passengers' arrival conditioned by the accomplishment of the "security check-in" and by the connection passengers' existence coming of another airlines.

## 4 SIMULATION OF THE SYSTEM

The simulation model was built in the ARENA platform according to the basic flowchart below.
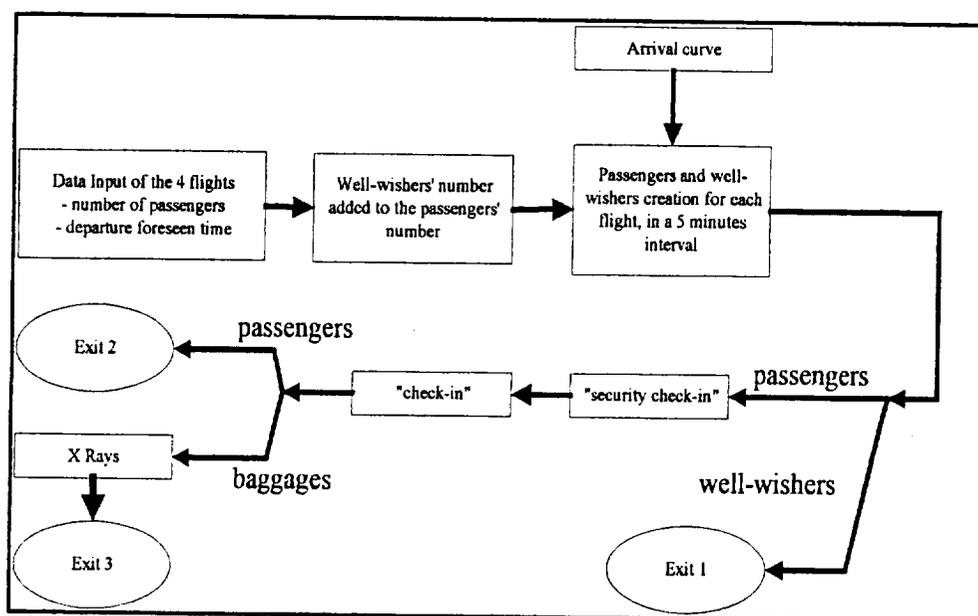


**Figure 6 – Flowchart of the model.**

In this model several parameters of the real system were inserted and the main of them are:
- rates of well-wishers per passenger;
- passengers' walk distances and speeds (Fruin);
- schedule and number of active counters;
- fails, shift changes and detailed verification of X Rays' machine;
- number and duration of the replications.

The validation of the model was made confronting the results of people/passengers' number in the "security check-in" and "check-in" queues with the data collected in practice, standing out such data always demonstrates just a tendency, not possessing the necessary statistical robustness to real validation of the model. The data of the Table 3 were used as input of the model.

# ACKNOWLEDGMENTS

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# APPENDIX 1

ATO arrival curve – AAL Brazil

ATO ARRIVAL CURVE
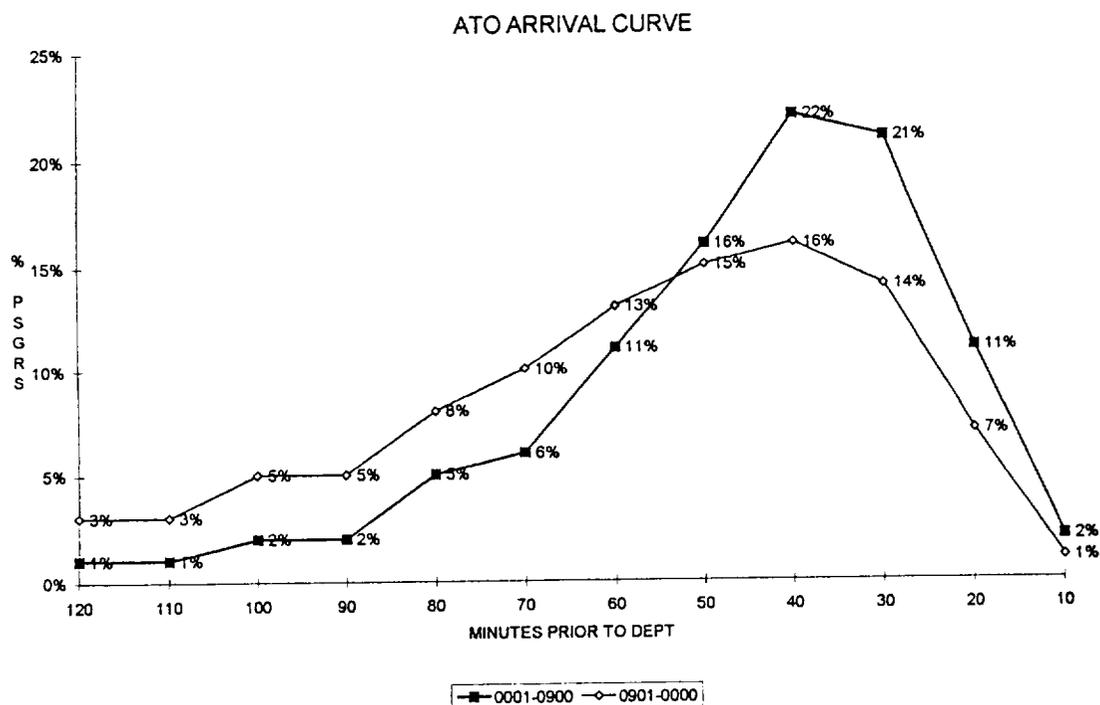
Table 3 – Input data.

| Flight | NPAX[1] | HPP | |
|---|---|---|---|
| | | hour | seconds |
| AA-950 | 115 | 21:45 | 13500 |
| AA-924 | 118 | 22:00 | 14400 |
| AA-906 | 94 | 23:00 | 18000 |
| AA-962 | 118 | 23:05 | 18300 |

1) data relative to the economic class of the referred
flights.

The application of the model is a good tool to analyze the capacity of the components in subject. It is taken the medium and maximum values of the number of people in the queue of "security check-in" and of "check-in", these values will be multiplied by an ergonomic index resulting in the demanded area. The used indexes are from Alves, being adopted as a passenger's width the value of 1 meter.

Table 4 – "Security check-in" areas.

| Service level | A | B | C | D |
|---|---|---|---|---|
| Queue of the "Security Check-in" ($m^2$/pax) | 0,70 | 0,60 | 0,50 | 0,40 |
| Area calculated with the average ($m^2$) | 23,8 | 20,4 | 17,0 | 13,6 |
| Area calculated with the maximum ($m^2$) | 138,6 | 118,8 | 99,0 | 79,2 |
| Area calculated with 80% of the maximum ($m^2$) | 110,9 | 95,0 | 79,2 | 63,4 |
| Existent area ($m^2$) | 100,0 | | | |

Considering that the service level A is the one applied to Brazilian international airports and that it should be considered an inferior value to the peak one (Alves & Almeida). The value of the existent area is compared with the value of the area calculated with 80% of the maximum value. It can be concluded that the area of the component in subject is under dimensioned around 10% facing the demand to it imposed. A solution for this under dimensioning would be the alteration of the operational procedures of the company so that these are appropriate to the existent area.

Table 5 – "Check-in" areas.

| Service level | A | B | C | D |
|---|---|---|---|---|
| Queue of the "Check-in" ($m^2$/pax) | 0,70 | 0,60 | 0,50 | 0,40 |
| Area calculated with the average ($m^2$) | 24,5 | 21,0 | 17,5 | 14 |
| Area calculated with the maximum ($m^2$) | 81,9 | 56,2 | 58,5 | 46,8 |
| Area calculated with 80% of the maximum ($m^2$) | 65,5 | 70,2 | 46,8 | 37,4 |
| Existent area ($m^2$) | 50,0 | | | |

The comments done previously continue being worth for the case of the "check-in" just being this one smaller at a rate of 25%. Showing that the need of operational changes is more evident than in the case of the "security check-in."

# Austin Bergstrom West Loop Cable System

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## 1.  BACKGROUND PROJECT JUSTIFICATION

Robert Mueller Airport has served the City of Austin, Texas, USA since the 1930's. Unable to purchase land needed to expand runway capacity for long-term aviation demand at the present Muller Airport, the issue was put to public vote. Voter referendums November 3, 1987, and May 1, 1993, confirmed the decision to develop a new commercial airport. Numerous studies identified the active Bergstrom Air Force Base as the preferred site.

Options of joint military-civilian use of the Air Force base were explored. In July 1991, a United State Congressional commission formally recommended that the base be closed. On August 1, 1991, the Austin City Council passed a resolution formally designating Bergstrom as the preferred site for a new commercial airport. The site is located 7 miles southeast of the Austin central business district but within the city limits.

At the Federal Aviation Administration (FAA), this project had to be submitted on fiscal year planning budgets and assigned a Congressional budget line item number. The budget line item number is used for the annual budget submittal to the United States (U.S.) Congress. Projects are prioritized and funded as monies are available. A project might go through the annual budget process as many as five times before being discarded or funded. Documentation of the problems and justification for the proposed action had to be submitted to Washington, D.C. and prioritized with other projects from across the United States of America. The City of Austin, Texas, made a commitment to provide portions of the funding to balance the federal government investment.

After the project successfully maneuvered this process, project authorization was given by Congress and monies assigned to the project. The FAA Southwest Regional Office staff was given project authorization and the assignment to proceed with the design. The Airway Facilities Division manages the airport facility projects built by the FAA including the loop cable system.

The conversion of an existing military air force base to a joint use or non-military airport poses special considerations. Issues and concerns become twofold with a planned additional parallel runway. Existing navigational aids (navaids) such as instrument landing systems, approach light systems, radar facilities, and remote radio sites must be replaced and/or upgraded and new navaids planned, designed and installed. Ultimately all components of the air traffic capabilities of the airport must be controlled and monitored at the airport traffic control tower (ATCT).

The navaids are controlled and monitored at the ATCT through a loop cable control system. The configuration and routing of a duct bank system to support the loop cable system is based on mandatory and non-mandatory FAA criteria, in-house review of the recommendations and coordination with the sponsor (airport owner).

Austin Bergstrom International Airport is the only new major activity airport under construction in the United States at this time. In addition to converting a former military base to a commercial airport, this project includes coordination of loop cable system and joint use of the system by the FAA and the City of Austin. This joint use has operations and financial implications beyond the usual relationship of FAA to sponsor.

## 2. ROUTING AND ALIGMNENT OF SYSTEM

The routing of the duct bank system took into account existing facilities, planned development, and possible future expansion of the runways, taxiways, and other use areas of the airport. The routing was altered to match up to the duct built by the City and shared with the FAA.

Also considered were the project's potential impact on known environmentally sensitive sites such as wetlands, flood plains, and capped landfills and potential interference with other existing and planned utilities both FAA and City of Austin. The US Air Force had conducted a comprehensive environmental survey as part of the base closing process. This survey had documented location and extent of capped landfill areas and refueling facilities. The project used the survey to avoid conflicts.

As a result of the planning, the duct bank system has been routed to within 200 feet of every navigational aid except the Airport Surveillance Radar. The radar was situated such that the Radar project will tap off the portion of the loop duct bank system than passes nearby along the east runway.

## 3. COORDINATION

Coordination has been a key element to the success of this project. The project began with coordination between various FAA departments and later expanded to include the City of Austin and the United States Air Force (USAF). Work on the project had to be coordinated with multiple and interrelated FAA projects at the site as well as with the sponsor's needs in scheduling, joint use facilities, and protection of environmentally sensitive sites and flood plains. See Figure 1, the Airport Layout Plan (ALP).

The FAA Southwest Region (SW) has guidelines for coordination in Order SW 6011.2C, Coordination of Approved F&E Projects. Coordination issues for this project were far reaching. From the FAA operational staff, air traffic controllers and NATCA to the City of Austin officials to the project overview personnel from Washington, D.C., coordination was a key element in the progress and success of this project.

### 3.1 Internal FAA

The various navaids are planned and designed by different groups within the FAA Region. Initially a preliminary loop cable / duct bank system layout was made by the project engineer. Then, due to construction scheduling and sequencing of funding, the project was broken down into an east loop and a west loop. Each loop would be fully functional and ultimate construction of each would parallel the construction scheduling of the related runway

Once the preliminary layout was complete, meetings were held with the various FAA navaids groups. The purpose of the meetings was to identify all planned facilities, determine alignment, delineate facility requirements and to agree on the type and capacity of

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cable to be used. The alignment was refined to ensure the duct bank would be routed near each of the necessary navaids.

The chosen routing had to coordinate and sequence with other FAA facilities and systems that would interface with the control tower. These facilities included three Radio Transmitter Receiver (RTR) sites, an Airport Surveillance Radar (ASR9), Instrument landing systems (ILS) for all four planned approaches, and approach lighting systems such as the three Medium Intensity Approach Lighting Systems with Runway Alignment Indicating (MALSR) for the three Category II approaches and an approach lighting system for the Category III approach.

The FAA Team was composed of representatives of many divisions and included regional and area field staff. Personnel from Airway Facilities came in the form of Regional Program Managers (RAPM), staff engineers, project managers and lead engineers, system specialists in the field and regional office; Air Traffic in the form of a regional representative, existing facility manager, air traffic controllers and union representatives. Security, real estate, telecommunications, contracts, legal and procurement were also included in the project and the review process.

The type of cable to be used was an issue of concern and was discussed at length early in the design phase. The FAA standard and Volpe Center recommendation has been a multi-mode fiber optic cable and related systems. This was due in part to FAA equipment such as the ASDE (airport surface detection equipment) which is hard wired with multimode fiber. The fiber optic industry in the United States had stabilized using single mode fiber as a standard. As a consequence, the termination equipment had dropped in cost and was approximately the same as for the multi-mode equipment. The approach has varied from airport to airport. Dallas/Fort Worth airport used single mode fiber optic cable. Houston Intercontinental Airport (now the George Bush Airport) has both multimode fiber to accommodate the ASDE and single mode for the rest of the interfacing equipment.

In addition, the FAA and other Airport Sponsors had experienced long line distance related problems with multi-mode fiber optic communications. Repeater equipment would be necessary for the lengths involved for multi-mode cable whereas with single mode cable, no repeaters would be required.


## 3.2    City of Austin

Initial contact was with the New Austin Airport Team, an extension of the downtown City of Austin officials. As the magnitude of the project was understood, building code officials, real estate, and legal representatives became more involved. The FAA makes every attempt to comply local codes, however, application of City codes to FAA facilities can be limited by FAA's sovereign immunity under U.S Public Law 100-678 to what the Federal government feels is "appropriate and beneficial". Working with the City of Austin, every attempt was made to comply with their local codes. The City was included in the 50% and 90% design reviews.

Working with the New Airport Team at the site, joint efforts coordinated the routing, construction schedules, joint use facilities and sequencing of the construction. Since this

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airport was being developed as a completely new airport by the City of Austin, there was extensive new communications duct bank infrastructure work to be done by the City. Early coordination with the City allowed for a unique situation with the FAA. The City of Austin began construction of the South access Road including duct bank in March 1995. By coordinating with the City, the FAA was able to add their required number of ducts to the City facility. This prevented a problem with construction sequencing that would have the FAA disturbing newly finished sponsor facilities to build their facilities.

In the past, the FAA has had sole ownership or clearly defined easements to facilities and other property including duct bank systems. Since there was extensive duct bank work by the City, early coordination allowed for a "common use" or "joint use" duct bank system for a significant portion of the fiber optic loop. The early coordination allowed the City to increase capacity of the duct bank in areas where FAA would need access. An agreement was reached whereby certain ducts in the City system were designated for FAA use. The FAA was to reimburse the City on a pro-rata basis for the ducts. The economy of scale resulted in a cost savings to the FAA of over $ 1.5 million. Had this not been done, the FAA would have disturbed new sponsor constructed facilities in order to install their duct bank. This coordination also allowed the alignment to match up to City built duct bank. This impacted the construction schedule as the FAA waited for portions of the bank to be built by the City.

The final result of this coordination was a reduction in cost for and construction of approximately 8 miles (13 km) of duplicate (or parallel) duct banks. Where, in the past, the FAA would have had to design and install over 16 miles (26 km) of duct banks for the primary and standby fiber optic loops, only 8 miles (13 km) of duct bank had to be constructed by the FAA.

As the project continued to develop, the City of Austin realized they needed conduit on the west outboard side of the airport for security monitoring. The FAA agreed to share the duct bank they built with the City. The FAA assessment to the City balanced the amount owed by the FAA. This sharing of duct banks allowed both entities to save money and to avoid disturbing newly built facilities.


## 3.3     United States Air Force

Early in the development of the duct bank design, the USAF Texas Air National Guard (TXANG) was occupying an area surrounding the new Airport Traffic Control Tower. This cantonment area needed to be crossed or the loop would have to be routed through the entrance into the tower site. Due to security, arrangements with the USAF to cross the cantonment area were difficult to make. When the U.S. Congress elected to close all military operations at Bergstrom, the TXANG wing at Bergstrom was relocated and the FAA was able to obtain more land at the airport traffic control tower (ATCT) site including the area needed for bringing the west loop into the west side of the ATCT.

# 4    DESIGN PHASE

## 4.1    Site Consideration

The standard guide for loop cable systems is FAA Order 6950.23A, Loop Cable Systems at Airport Facilities, 5/23/83. It establishes the program, planning and implementation guidelines for upgrading power and control/signal system supporting the National Airspace System (NAS) at major airports. The scope applies to intermediate and major activity level airports. The cable system is to form a loop where major construction and installation projects are planned which require numerous cable runs and where cost effective (see Figure 1, ALP). The loop system should provide for existing and planned facilities which include power, signal and control cables.

Items for planning consideration include how important is the facility, impact of facility location, redundancy requirements, method of installation, cost of system and ability to combine several facilities within the same system. Also of consideration would be the reliability and maintainability of the selected system.

Fiber optic cables should be considered as they are impervious to lightning induced surges, noise effects from power cables, and are of a smaller diameter than equivalent metallic conductor cable. Fiber optics should also be considered where the master plan indicates remote maintenance monitoring and control cable are to be installed.

FAA Order 6650.8, Airport Fiber Optic Design guidelines, 8/14/89, outlines fiber optics as a communication medium and establishes the basic and detailed requirements for the system. The loop must be a closed path providing inherent redundancy. The configuration must consider the number of facilities, only two or three or more. The protocol is defined for a loop shared by three or more facilities.

FAA Order E-2761B, Cable, Fiber-Optic, Multi-mode, and Single Mode, Multi-fiber, 5/10/9, indicates specifications for multi-mode or dual-window single mode fiber. There are four types fiber are defined. Type A, a six-fiber, gel-filled, non-armored, totally dielectric; Type B, Same as Type A but with a polyvinylidene fluoride sheath for hydrocarbon fuel protection; Type C, same as Type B but with corrugated bimetallic (copper over stainless steel) armor for direct earth burial installation; and Type D, two-fiber tight buffer cable for interior use. There are considerations for temperature, the presence of grade index, hydrocarbon fuels; requirements for materials, attenuation, storage, installation, protection and testing.

FAA Order 6950.23, Cable Loop Systems at Airport Facilities was issued so control and signal cable configured in a loop would be initiated with the establishment of weather system projects such as low level wind shear alert (LLWAS) or system VORTEX advisory system. The National Air System Plan (NASP) expanded the cable loop philosophy to include power cables. This order designates all intermediate and major level airports shall, where cost effective, provide a cable system configured in a loop around the airport.

Items to consider included facility location and importance, redundancy requirements, methods of installation, costs, and combining of several facility requirements in the same system. Reliability and maintainability of the system selected will be of prime importance.

Where new control/signal cable system is required, fiber optic cables should be considered since they are impervious to lightning induced surges, noise effects from power cables, ability to co-mingle fiber optic and copper cable in the same trench, and fiber is of a smaller diameter. Fiber optic cable will allow the use of superimposed signals for various control and signal needs.

The earliest design choices to make were the location of the fiber optic nodes where fiber to copper interfaces would be made. The remote transmitter receiver sites and MALSRs were at the furthest corners of the airport. The probable phasing out of the MALSRs as GIS is utilized meant the sites would be abandoned. The RTRs are expected to be permanent and were the logical choice.

The loop was routed by the site with an off and on lead going to the RTR building. Extensive coordination was required as the final construction design drawings and ultimate construction of the loop cable systems and the RTR sites would be taking place at different times over a two year period. To offset this difficulty, however, a single engineering firm was used to provide the construction drawings and the engineering for each of the projects was kept under one single Project Manager. As a result, interface problems were virtually non-existent.

## 4.2    Environmental Elements

As previously mentioned, the new airport was to be sited on the location of an existing United States Air Force Base. During the closure of the Base, a comprehensive Environmental Study had been performed to identify any environmentally hazardous locations and the types of materials that might be found at those locations. In addition, the under FAA Orders and Standards, a duct bank is categorically excluded from the Environmental Due Diligence Audit (EDDA) requirement if the sponsor is willing to include a hold harmless clause in the lease. If not, the FAA was obligated to perform an independent EDDA per FAA Order 1050.19. Due to the coordination of the FAA with the City, a design which avoided documented trouble areas, and co-location of duct bank system with the City, an EDDA was not conducted for the duct bank.

Investigation into the Air Force and City provided environmental reports confirmed the presence of various known and unknown contaminants along the loop cable route. FAA then worked with the City and the Air Force, to avoid hazardous areas. It is important to note that this coordination took place early on in the project. This allowed for needed re-alignment while engineering design was still under way. Had this been done at a later time, the construction of the facility could have been significantly delayed.

## 4.3    Unique Features

Unique features of this project include environmental considerations, manhole and duct bank sharing between the FAA and the City of Austin, soils considerations for the movement of long duct banks in poor soil condition, and joint restricted access permitting.

FIGURE 1

EAST LOOP DUCTBANK

ASR-9

ILS/ALS SHELTER

ILS/ALS SHELTER

ONION CREEK

BURLESON ROAD

EAST RUNWAY

ATCT

WEST RUNWAY

TERMINAL

RTR #3

ILS/ALS SHELTER

RTR #1

WEST LOOP DUCTBANK

RTR #2

ILS/ALS SHELTER

U. S. HIGHWAY 183

STATE HIGHWAY 171

8
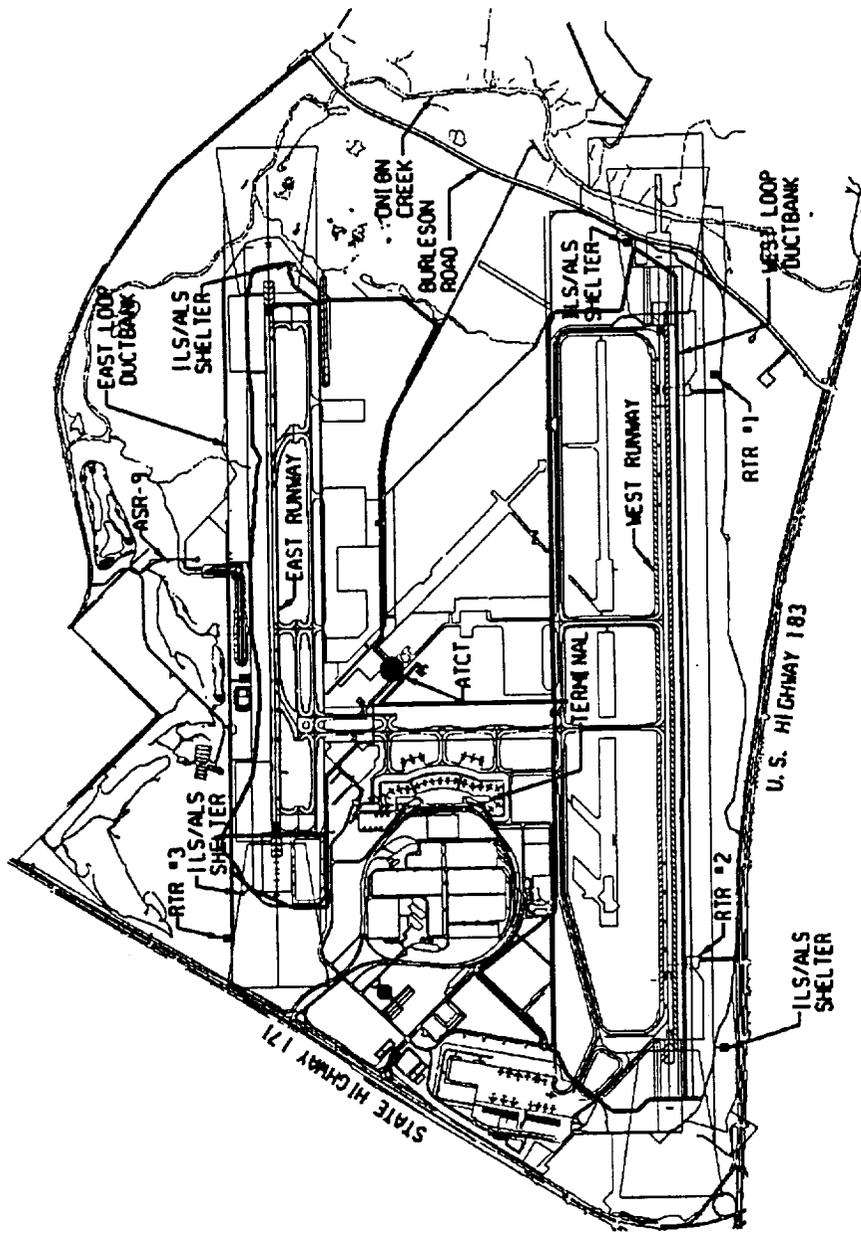
The FAA Southwest Region had adopted a standard duct bank section using 4-inch ducts, set with spacers, concrete encased and marked with electronic ball markers. Due to the expansive soil conditions at Bergstrom Airport, a different cross section was to be used. The duct bank was designed using 4-inch polyvinyl conduits (PVC), set with spacers and bedded with sand. This sand was capped with 4-inches of concrete. Red dye powder was used in the concrete as a warning to anyone digging in close proximity. The ball markers were placed on top of the concrete. The facility will be given an electronic wand to be used to locate the duct bank via the electronic ball markers.

## 5    CONSTRUCTION AND PRESENT STATUS

The construction of the west loop began in 1996. The contractor built the FAA portions of the system and left the project until the City of Austin had completed their portions. The contractor came back to the site in early 1997 and installed the cable for the entire west loop system, taking the cable to the demarcation point in the ATCT  The system is now fully functional.

The construction of the east loop started in the fall of 1997, once final grades of the new east runway had been established and the duct portion was completed as of February 1998. Installation of the fiber optic cable and final commissioning of the complete loop cable system is expected by March, 1998. The east loop is 98% complete including fiber as of June 1998. Interfacing with east runway navigational aids will be completed as each system is installed and brought on line.

The airport traffic control tower electronics are scheduled to complete in September 1998, with the tower ready for commissioning in October 1998. Austin Bergstrom Airport began air cargo operations in July 1997 and is scheduled to begin commercial operations in May 1999.

In summary, this project was successful due to extensive coordination between the FAA and the airport sponsor. Environmental impacts were minimized by awareness of existing concerns and avoiding them. Financial gains were realized by the City of Austin, the FAA and the U.S. taxpayer as joint use facilities saved money during design and construction.

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FAA Order 6950.23, Cable Loop Systems at Airport Facilities

FAA SW Order 6011.2C, Coordination of Approved F&E Projects

FAA Order 1050.19, Environmental Due Diligence Audits in the Conduct of FAA Real Property Transactions

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# An Optimum Resource Allocation Model for Airport Passenger Terminals

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## Introduction

There has been little research to involve optimization theory in the planning, design, and operation of airport PTBs. The only exception is development of a design methodology, based on the heuristic modelling technique, to produce an optimum terminal design (1). The methodology is composed of three major algorithms; facility sizing algorithm, the load assignment algorithm, and the facility layout algorithm. This methodology determines the minimum amount of areal spaces first, and second the loads are assigned to the facilities in such a way that transport cost, expressed as the sum of the products of passenger flow times distance, is at minimum. Then the facilities are located relative to each other in such a manner that the transport cost is also at a minimum. The second and third steps are iterated until an optimum design has been obtained. The methodology is very useful in planning and design in terms of optimum concept selection. It does not deal with the PTB components in detail in terms of operating characteristics and stochastic demand.

In this research, the whole PTB is considered as a system in which labor, capital, and services are deployed to produce certain services to passengers. The function of this complex system may be seen as taking a passenger and providing some services to that passenger. This provision of services is associated with some cost to operators as well as passengers. For example, operating and maintenance costs which constitute a major portion of the total cost, has been almost always neglected in the current planning and design procedures. Operating and maintenance costs can be reduced by a reduction in level of service, especially at peak periods, but at some cost to the passenger. The least cost solution may not be always the best solution for the passenger. On the other hand, terminal configurations that supposedly offer high levels of service may be expensive to operate. Those costs will be ultimately paid by the traveller either through higher fares, or other user charges. Optimizing the associated costs with the PTB operation is the subject of the optimization model discussed in this paper.

## Optimization Theory

The research problem addressed in this paper is that given a fixed amount of resources, e.g., PTB space, the process should determine the allocation of all or part of the resources to a series of activities, with variable demand, in such a way that the objective function under consideration is optimized. The problem addressed here is a resource allocation problem with a series of constraints.

The resource allocation problem is generally formulated as follows:

*Minimize* $f(x_1, x_2, ..., x_n)$

subject to: $$\sum_{j=1}^{n}(x_j)=N \ , \quad x_j \ \rangle \ 0 \qquad (1)$$
$$j=1,2,3,..,n$$

That is, given one type of resource whose total amount is equal to $N$, it is desired to allocate it to $n$

segments which serve an uncertain number of customers so that the objective value $f(x)$ becomes as small as possible. The variable $x_j$ in Equation 1 represents the amount of resource allocated to segment $j$. If the resource is not divisible, e.g., persons, processors, then the variable $x_j$ is a discrete variable that takes nonnegative integer values. In this case, the constraint $x_j$ = integer, $j$ = 1,2,3,...,n is added to Equation 1.

The objective function in general form, i.e., Equation 1, cannot be used for airport PTBs due to the fact that one may have more resources than what is required. A special objective function for this problem should be developed in such a way that the allocated resources may be smaller or equal to the total resource available. The objective function for this research problem is as follows:

$$\text{Minimize:} \quad \sum_{j=1}^{n} C_j x_j$$
$$\text{subject:} \quad \sum_{j=1}^{n} (x_j) \leq N, \quad x_j \rangle 0 \quad (2)$$

where,

$c_j(x_j)$ = expected over- and under-supply cost of allocating $x_j$ to segment $j$,

$x_j$ = resource allocated to segment $j$, e.g., space,

$n$ = total number of PTB segments,

$N$ = total amount of available resource, e.g., PTB passenger processing area.

There are two types of costs associated with the allocation of resources, i.e., over- and under-supply cost. Over-supply cost is the cost of providing resources more than what is required and under-supply cost is the cost of not providing enough resources to meet the demand. Moreover, allocation of resources depends on the demand placed upon the facility. The demand at each segment is also uncertain and depends mainly on the flight schedule. Taking all the variables into consideration, the expected over- and under-supply cost function for the PTB is found as follows:

Assume that $y$ is the demand variable at each segment and $p_j(y)$ is the Probability Mass Function (PMF) for variable $y$ at segment $j$. This means that the probability of having $y$ units of demand at segment $j$ is $p_j(y)$. It is also assumed that each unit of demand needs $\theta_j$ units of resource at segment $j$, e.g., the amount of space that each passenger occupies. If $x_j$ is the amount of resource supplied to segment $j$, then the expected amount of over-supply resources would be:

$$\sum_{0}^{\delta_j} (x_j - \theta_j y) p_j(y) \quad (3)$$

where,

$x_j$ = the amount of resource supplied,

$y$ = demand variable, i.e., number of passengers,

$p_j(y)$ = probability of having y units of demand at segment $j$,

$\theta_j$ = the amount of resource needed by each demand unit, LOS,

$\delta_j$ = integer $(x_j / \theta_j)$.

To calculate the cost associated with the amount of over-supply resources, the unit cost of over-supply at segment $j$ should be found. If $\alpha_j$ is assumed to be the unit cost of over-supply at segment $j$, then the over-supply cost at this segment is as follows:

$$\alpha_j \sum_{0}^{\delta_j} (x_j - \theta_j y) p_j(y) \quad (4)$$

As was mentioned, if the resources supplied to segment $j$ were less than required then there would be an under-supply cost. Following the same process and assuming $\beta_j$ to be the unit cost of under-supply, the expected under-supply cost would be:

$$\beta_j \; \Sigma_{\delta_j}^{Y} \; (\theta_j y - x_j) p_j(y) \tag{5}$$

where,
$Y$ = maximum expected demand for segment $j$,
$\beta_j$ = the unit cost of under-supply.

Therefore, the total cost associated with the allocation of $x_j$ resources to segment $j$ is the sum of the two preceding cost elements,

$$C_j X_j = \alpha_j \; \Sigma_0^{\delta_j} (x_j - \theta_j y) p_j(y) + \beta_j \; \Sigma_{\delta_j}^{Y} \; (\theta_j y - x_j) p_j(y) \tag{6}$$

By solving Equation (6) for different values of $x_j$, the optimum resource value associated with the minimum total cost, for one specific segment, can be found. Since the PTB system consists of several segments for which resources should be allocated, the total expected over- and under-supply cost for the whole system would be as follows:

$$C_T = \Sigma_{j=1}^{n} C_j X_j = \Sigma_{j=1}^{n} [\alpha_j \; \Sigma_0^{\delta_j} (x_j - \theta_j y) p_j(y) + \beta_j \; \Sigma_{\delta_j}^{Y} \; (\theta_j y - x_j) p_j(y)] \tag{7}$$

where,
$C_T$ = total expected over- and under-supply cost of the PTB system,
$n$ = maximum number of PTB segments.

It is hardly possible to find an absolute mathematical solution for the preceding equation in which the resources and demand were assumed indivisible. It is possible to solve this equation numerically or by computer programs and provide the values of $x_j$ for all predefined segments of the PTB.

However, if the resources and demand were assumed to be divisible, then $x_j$ and y are continuous variables that can take any nonnegative real values. In this case following the same procedure of indivisibility, the total over- and under-supply cost function for segment $j$ would be as follows:

$$C_j X_j = \alpha_j \int_0^{\delta_j} (x_j - \theta_j y) dF_j(y) + \beta_j \int_{\delta_j}^{\infty} (\theta_j y - x_j) dF_j(y) \tag{8}$$

where,
$F(y)$ = cumulative distribution function of demand at segment $j$ which is continuous and increasing,
$\theta_j$ = constant representing the amount of required resource for each unit of demand function,
$\alpha_j$ = unit cost of over supply at segment $j$,
$\beta_j$ = unit cost of under supply at segment $j$.

The cost function for the continuous case, Equation 8, can be rewritten as follows:

$$C_jX_j=\alpha_jx_j\int_0^{\delta_j}dF_j(y)-\alpha_j\theta_j\int_0^{\delta_j}ydF_j(y)+\beta_j\theta_j\int_0^{\infty}ydF_j(y)$$
$$-\beta_j\theta_j\int_o^{\delta_j}ydF_j(y)-\beta_jx_j\int_0^{\infty}dF_j(y)+\beta_jx_j\int_0^{\delta_j}dF_j(y) \tag{9}$$

If $\mu_j$ is defined as the mean of $F_j(y)$ then by using the principles of probability theory such as:

$$\int_0^{\infty}dF_j(y)=1.0 \quad ; \quad \int_0^{\infty}ydF_j(y)=\mu_j \tag{10}$$

the preceding equation would simplify to the next equation, i.e:

$$C_jX_j=\beta_j\theta_j\mu_j-(\alpha_j+\beta_j)\theta_j\int_0^{\delta_j}ydF_j(y)+(\alpha_j+\beta_j)x_j\int_0^{\delta_j}dF_j(y)-\beta_jx_j \tag{11}$$

Equation 11 would be further simplified to,

$$C_jX_j=\beta_j(\theta_j\mu_j-x_j)+(\alpha_j+\beta_j)(x_jF_j\delta_j)-(\alpha_j+\beta_j)\theta_j\int_0^{\delta_j}ydF_j(y) \tag{12}$$

Therefore, the only integral left in Equation 12 is analyzed as;

$$\int_0^{\delta_j}ydF_j(y)=\int_0^{\infty}ydF_j(y)-\int_{\delta_j}^{\infty}ydF_j(y) \tag{13}$$

The first part of Equation 13 is equal to $\mu_j$ and the second part can be solved by using the following expected value theory (2):

$$\int(x>\alpha)xdF(x)=\alpha(1-F(\alpha)+\int_{\alpha}^{\infty}((1-F(x))dx \tag{14}$$

Replacing $X$ with $y$, $\alpha_j$ with $\delta_j$ and $F(x)$ with $F_j(y)$ leads to,

$$\int_{\delta_j}^{\infty}ydF(y)=\delta_j(1-F(\delta_j)+\int_{\delta}^{\infty}((1-F(y))dy \tag{15}$$

The integral in Equation 15 is analyzed to,

$$\int_{\delta_j}^{\infty}(1-F(y))dy=\int_0^{\infty}(1-f(y))dy-\int_0^{\delta_j}((1-F(y))dy \tag{16}$$

The second integral can be broken into two parts, Equation 16 would simplify as;

$$\int_{\delta_j}^{\infty}(1-F(y))dy=\mu_j-\delta_j+\int_0^{\delta_j}F(y)dy \qquad (17)$$

Finally by substituting Equation 17 into 13 and substituting Equation 13 into 12, the total cost function would be simplified to a determinate function in which all of its elements can be calculated,

$$C_jX_j=\beta_j\theta_j(\mu_j-\delta_j)+(\alpha_j+\beta_j)\theta_j\int_0^{\delta_j}F(y)dy \qquad (18)$$

Considering that $\delta_j=x_j/\theta_j$ then the preceding equation can be written with respect to $x_j$,

$$C_jX_j=\beta_j\theta_j(\mu_j-\frac{x_j}{\theta_j})+(\alpha_j+\beta_j)\theta_j\int_0^{\frac{x_j}{\theta_j}}F(y)dy \qquad (19)$$

If the demand function is known , the absolute value for $x_j$ can be found by solving Equation 19 mathematically. To find the optimum value for $x_j$, the derivative of the final equation with respect to $x_j$ should be taken, i.e:

$$C_j'X_j=-\beta_j+(\alpha_j+\beta_j)\theta_jF(\frac{x_j}{\theta_j}) \qquad (20)$$

If the value of derivative is substituted by zero, and then by solving the derivative with respect to $x_j$, the absolute value of $x_j$ is found. From the Equation 19 and its derivative ($F_j$ is increasing) it is also clear that the cost function is convex with respect to variable $x_j$ which means that there is a minimum point in the cost function.

So far, the equation for finding the optimum resource value for one typical segment of the PTB based on the minimum over- and under-supply cost was found. The objective function was to minimize the expected total cost of operating the whole PTB system consisting several segments. Therefore, the problem would be a resource allocation problem with a separable convex objective function. There are few approaches to solve the allocation problems of type Equation 1 in which the total amount of resources, $N$, would be allocated among the segments. If the demand function and the values for $\alpha_j$ and $\theta_j$ are known, then Equation 5.1 can be written as a series of nonlinear separable convex functions which have to be optimized. In another words the values of $x_j$ should be found in such a way as to minimize the expected cost function. Then knowing all the variables and constants, algorithms have been developed, e.g., RANK or RELAX, to find the optimal values for $x_j$ (3). It should be noted that several assumptions are inherent in these algorithms. For example, these algorithms minimize the sum of convex objective functions of one variable under a simple constraint that all variables sum to a given constant, i.e., maximum resource available. They also assume that each objective function is strictly convex, i.e., has a defined mathematical function that its derivation is increasing in $x_j$. These assumptions are not supported for airport PTBs in which hardly all resources are fully utilized and the demand function cannot be defined mathematically.

The objective function of this research problem is more complex due to the fact that the sum of allocated resources could be less than or equal to the maximum resource available. Except for some approximation procedures, no formal, computationally mathematical solution exist for optimally solving Equation 2. In addition, more complexities exist within the equation such as the exact demand

function, and the unit costs for over- and under-supply. Due to the stochastic nature of passenger arrival and departure at the PTB, no specific mathematical function can represent the actual demand on the system at each instant of time.

Another difficulty associated with the mathematical approach is finding values for $\alpha_j$ and $\beta_j$. The value of $\alpha_j$ depends on the unit cost of over-supply of a facility or activity which is going to be performed, e.g., design, construction, operation and maintenance. The value of $\alpha_j$ can be obtained by going through a cost allocation process. First, all the cost items associated with the PTB's operation should be estimated. Second, the sum of these costs should be divided by the total amount of resources available. Then the cost of providing one unit of extra resource can be obtained. For example, the procedure for the estimation of the operational cost of over-supply, $\alpha_j$, is summarized as follows:

$$\alpha_j = OPS_{total}/RES_{total} \qquad (21)$$

where,
$OPS_{total}$ = total PTB operational and maintenance cost
$RES_{total}$ = total resource available such as space, labor.

The value of $\beta_j$ is the most difficult to estimate. The question to be answered is how much would be the cost to the operator if resources are provided one unit less than what is required? In the case of multiple airports, the operator at one airport may lose customers due to the availability of better service at another location. One approach is to put monetary values on the amount of discomfort such as: congestion, delay, walking distance, etc. experienced by passengers. This approach is interpreted as a social cost estimation which would give an impression of the under-supply cost from a users' point of view.

**Optimization Model Development**

Existing optimization algorithms, e.g., RANK, RELAX , in combinatorial optimization were examined to see if they could be used to solve the developed optimization problem. The results were negative due to the fact that in an airport PTB, not all resources need be allocated and no mathematical function can represent the variable demand distribution on the PTB segments. Since the assumptions of these algorithms are not supported by the real life PTB operation, an algorithm was developed from first principles. A simplified flow chart of optimization program is shown in Figure 1.

The algorithm of the program consists of mainly two parts, i.e., optimization and sub-optimization. In the optimization part no constraint has been set for the maximum amounts of available resources, while in the sub-optimization part the maximum amounts of available resources are limited. The mechanism of the optimization program is summarized as follows:

The only inputs to the program are the Probability Mass Functions (PMFs), obtained from a Terminal simulation model and variables of $\alpha_j$, $\beta_j$ and $\theta_j$. The PMFs for different segments of the PTB are saved in separate data files. Each data file contains the population distribution function for 24 hour time periods of a typical day for a specific segment of the PTB. The relative values of $\alpha_j$ and $\beta_j$ are

assumed based on engineering judgement or historical data. From the analysis it was found that the absolute values of $\alpha_j$ and $\theta_j$ do not change the final results if their relative value, remains constant. The variable $\theta_j$ will represent the level of service concept within the optimization. In another words, $\theta_j$ represents the required resource value for each demand unit at each LOS.

The most common quantitative factors that influence level of service in PTBs are congestion which is measured in terms of number of passengers per unit area, queue length, and waiting time (4,5,6). Transport Canada (4) proposed a comprehensive level of service assessment method based on providing ``space" at different PTB components. The method which was subsequently adopted by International Air Transport Association (5), established six different levels of service based on space provision. The boundaries for the various PTB facilities are shown in Table 1.

Table 1: LOS Targets for PTB Components, (4)

| Terminal Component | A to B | B to C | C to D | D to E | E to F |
|---|---|---|---|---|---|
| Check-in | 1.6 | 1.4 | 1.2 | 1.0 | 0.8 |
| waiting areas | 2.7 | 2.3 | 1.9 | 1.5 | 1.0 |
| Holdroom | 1.4 | 1.2 | 1.0 | 0.8 | 0.6 |
| Baggage claim | 1.6 | 1.4 | 1.2 | 1.0 | 0.8 |
| PIL area[1] | 1.4 | 1.2 | 1.0 | 0.8 | 0.6 |

Data files containing the PMFs are opened and scanned into the program. The time of the day is divided into equal time periods, e.g., one hour long. Within one time period, the procedure will find the optimum required resources for different segments of the PTB. The program calculates the over-and under-supply costs associated with each resource value. Then the resource value associated with the minimum total over- and under-supply cost is called optimum required resource.

The sum of optimum resource values for all PTB segments during first time period is compared with the maximum existing resources, e.g., total PTB processing area. If the sum of resources is smaller than the maximum value, then the time is incremented and the same process is repeated for all other time periods. If the sum of resources for all segments at a specific time period is greater than the maximum existing resource, the process will start to sub-optimize the system.The optimization process will find the optimum resources without any constraint at a global minimum total cost. Having the constraint of limited total resources, the optimum values will be adjusted at a price of increased total cost.

The sub-optimization process will be done in such a way to minimize the increased cost to the total expected over- and under-supply cost. Therefore, the process will find the optimum resource value of the segment associated with the minimum value of under-supply unit cost, $\theta_j$. The optimum resource value of the segment will be decremented until the sum of resources for all segments is equal

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[1] Preliminary Inspection Lines for Passport Control.

to the maximum existing resource. It should be noted that the resource value of any segment cannot be decremented lower than its minimum value. The minimum resource value for each segment could be the required resources at the lowest operating service level. Transport Canada (4) recommends level of service C as a design standard, as it provides good level of service at a reasonable cost. However, the minimum level of service can be defined by the user.

The sum of the new optimum resources of various segments will be compared with the maximum existing resources and if it is still higher than the maximum, another segment with the second lowest $\beta_j$ will be chosen for sub-optimization. If the values of $\beta_j$ for two segments are equal, then the segment with the higher unit cost of over-supply, $\alpha_j$, will be chosen. The rationale is choosing the segments for sub-optimization which have the least impact in the total cost increase. As mentioned earlier, the cost of operating different segments of the PTB may be different due to the type and the cost of facilities involved in their operation. From the analysis, it was found that the lowest $\beta_j$ and the highest $\alpha_j$ have the minimum impact on the total over-and under-supply cost. This process is repeated until the sum of the optimum required resources are equal to the maximum availabe resources.

The output of the optimization program would be the optimum resource values in a variable time-space plan format. The program will also provide the associated supply costs of resources for a 24-hour period. How close one can bring the practical plan to the theoretical plan depends on the flexibility of the physical layout and other constraints, e.g., traffic demand pattern.

The sum of optimum resource values from various segments multiplied by the unit cost of providing resources is the total cost of operating the PTB at each instant of time. If all the conditions are met, the operational and maintenance cost would be a function of demand distribution. Therefore, one of the objectives of this research, which was to produce a variable time-cost plan as opposed to a fixed cost plan, is achieved. This optimization procedure, if applied properly, will result in significant savings on the operation and maintenance costs of PTBs over long time periods.

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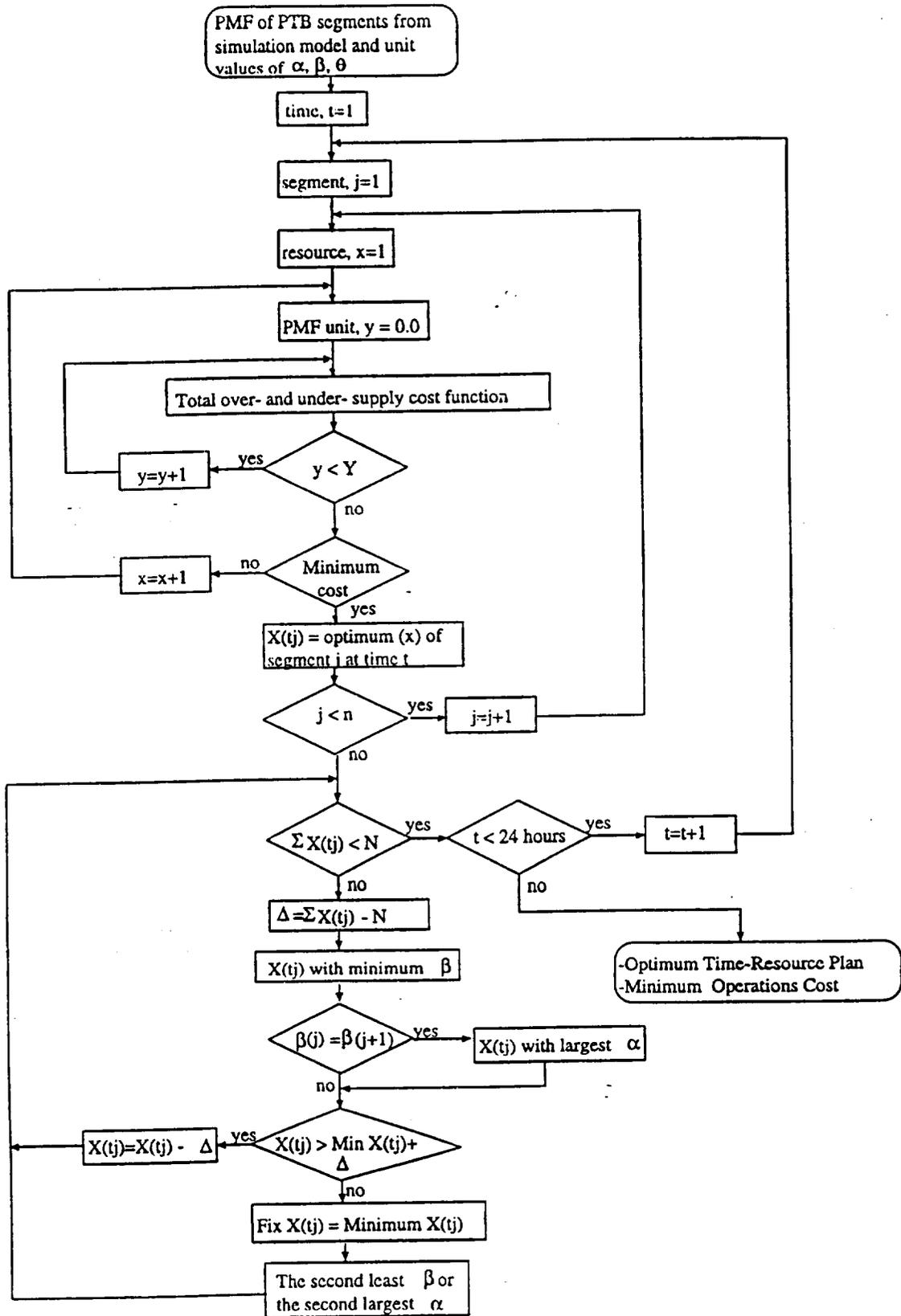
Figure 1: Flowchart of the Optimization Program

# REPORT DOCUMENTATION PAGE

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The Air Transport Research Group of the WCTR Society was formally launched as a special interest group at the 7$^{th}$ Triennial WCTR in Sydney, Australia in 1995. Since then, our membership base has expanded rapidly, and now includes over 400 active transportation researchers, policy-makers, industry executives, major corporations and research institutes from 28 countries. It became a tradition that the ATRG would hold an international conference at least once a year. In 1998, the ATRG organized a consecutive stream of 14 aviation sessions at the 8$^{th}$ Triennial WCTR Conference (July 12-17: Antwerp). Again, on 19-21 July, 1998, the ATRG Symposium was organized and executed every successfully by Dr. Aisling Reynolds-Feighan of the University College of Dublin. The Aviation Institute at the University of Nebraska at Omaha has published the Proceedings of the 1998 ATRG Dublin Symposium (being co-edited by Dr. Aisling Reynolds-Feighan and Professor Brent Bowen), and the Proceedings of the 1998 WCTR-ATRG Conference (being co-edited by Professors Tae H. Oum and Brent Bowen).