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

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

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

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

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

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

The Air Transport Research Society (ATRS) World Conference

July 10-12, 2003   Toulouse, France

THE CONFERENCE

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

THE PROCEEDINGS

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CONVENIENT AIRPORTS: POINT OF VIEW OF THE PASSENGERS

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ABSTRACT

The competition among airlines or among airports aiming at to increase the demand for its services has been more and more incited. Knowledge the perception of the users for the offered services means to meet the customer's needs and expectations in order either to keep the customer, and therefore keep a significative advantage over competitors.

The passenger of the air transportation wants rapidity, security and convenience. Convenience can be translated by comfort that the passenger wants for the price that he can pay. In this paper had been identified, as a result of a survey achieved in six Brazilian airports during 2002, the best indicators in the passenger's perception. These indicators among any others were listed in the handbook of Airports Council International (ACI). Distinctive perceptions were observed among passengers with different travel motivations.

This survey had been carried through in the airports of Brasilia, Porto Alegre, Salvador, Fortaleza, Curitiba and Belém. Considering this survey we can identified the most attractive airport among them.

This work is a way to help improve quality of service, in particular, in these six airports of the Brazilian network. The results should be published and made available to all the parties concerned (airport authority, airlines and service providers) and should lead to corrective action when the passenger is not satisfied with the service.

Keywords
Terminal, passenger, quality, service, installations, metodology, measurement

INTRODUCTION

In the last decades, the airports had passed not to be simple terminals for the exchange in transport ways. New functions had been inserted, receiving multiple services and becoming true centers of purchase, making possible the access of new users the offered services.

Today, the quality, more than a modism became essential for the valuation of the services, in any industry, any market. The perception of quality of the airport terminals depends on some factors. One of them if relates to the proper characteristics of the passengers. Others can be linked to the architectural concept used in the conception of the terminal and its installations.

In Brazil, the air transportation and the airports are in process of transition with the modernization of the airports and the entrance in the market of airlines with different plans of work and levels of service.

The airports managed for the INFRAERO concentrate 97% of the movement of the regular air transportation in Brazil, representing, in 2001, 2.1 million landings and takes-off of national and foreign aircraft, carrying 73,9 million passengers and 1,25 million of tons of load. In 2001, the invoicing was of R$1,47 billion. For 2002, the company had the

perspective of superior growth 8% in the movement of passengers and foresees investments of the order of R$ 900 million in projects and services in the airport sector.

Currently the airports are dealing with customers who demand different installations and services. All this situation is generating discussion about the quality and level of offered service.

Based in the indicators of quality raised by the Airports Council International (ACI, 2000), this work evaluates 6 Brazilian airports terminals for the indicators identified for the ACI and develops a methodology of evaluation of the quality in airports terminals, based in the perception of the passengers. With this, planners and operators of airports, that intend to create or to extend, start to make use of a methodology to identify to the characteristics or the aspects that more contribute for the perception of quality of services at airports for users, making possible to the professionals to undertake solutions who contribute for a large perception of quality, making possible after all the biggest satisfaction of the customers (passengers) inside of airport terminals.

QUALITY INDICATORS
Currently, the airports are endowed with diverse operational areas with systems and processes that are linked. With this, the users can try and evaluate the quality offered for the installations of the airport. Each process can consist in a quality indicator and all in set can produce a quality global that can be identified in relation to the offered service.

Thus, one searchs to identify to the indicators of quality in each operation of the airport and its installations, where each stage of processing can be considered as a link of a chain of services.

The IATA (1991), (International Air Transport Association), it developed ADRM (Airport Development Reference Manual), establishing indicators of quality for the development of airport terminals under the optics of the passengers.

They are indicators established by the IATA:

- easiness of access to the airport through highway or train;
- lesser distances of the curb to check-in and check-in to the gate of embarkment without changes of levels;
- lesser distances of the aircraft the area of restitution of luggage and customs and of customs to the curb or the station of train;
- attractive and surrounding architecture that provides a relaxation atmosphere;
- lesser lines in the security and control of passports;
- agility in the departure of the aircraft;
- fast restitution of luggage with ample mats;
- clear and concise visual communication;
- variety of store;
- rest area, conveniently leased close to the embarkment gate;
- good restaurants and the moderate prices.

It is verified that diverse observed factors as indicating of quality of service exist. These indicators can be most important at the moment of the accomplishment of the survey, being able to vary as: time of the survey applications (seasons), type of passenger and trip, local culture and application of the survey (with the passengers or the operators of the airport).

In this work it was adopted as main reference to the survey carried through for the ACI (2000), Quality of Service at Airports: Standarts and Measurements, that if classified from a world-wide survey the indicators of quality in the current airports.

ACI indicators

For the development of the survey had been adopted the indicators that had received the largest concept in the survey from the ACI (2000).

The passage carried through for the passenger in the embarkment processing was considered in the proposal. This passage is represented by three areas of measurement, that contains the quality indicators that they will be evaluated and appraised for the passengers.

The measurement areas are:
- processing time;
- available areas (services/facilities);
- level of comfort and quality of attendance.

One considered in the embarkment flow the following sectors:
- access to the airport;
- hall of passengers;
- check-in;
- security check;
- embarkment room.

To follow, the quality indicators that will be evaluated and appraised for the passengers:

The indicators that will be evaluated in the access to the airport/terminal are:
- general signalling;
- vacant number;
- variety of transports.

The indicators that will be evaluated in the hall of passengers are:
- available areas;
- distance between instalations/components;
- availability of elevators/escalators;
- availability of stands of luggage;
- thermal comfort;
- acoustic comfort;
- visual sensation (esthetic);
- availability/confort of seats;
- availability of the signaling;

- availability/cleannes of the sanitary;
- general security;
- general cleanness;
- general satisfaction for the given services/quality of the service.

The indicators that will be evaluated in essential commercial services are:
- practised prices;
- available areas;
- quality of the attendance;
- variety of installations.

The indicators that will be evaluated in the information services are:
- availability of the service;
- quality of the attendance.

The indicators that will be evaluated in the FIDS (flight information display system) are:
- FIDS availability.

The indicators that will be evaluated in check-in are:
- processing time;
- available area;
- cordialidade of the attendance.

The indicators that will be evaluated in security check are:
- processing time;
- available area;
- attendance.

The indicators that will be evaluated in the departure lounge are:
- available services;
- confort/availability of seats;
- available area;
- cleanness;
- thermal comfort;
- acoustic comfort;
- visual sensation (esthetic).

Application of the indicators (location survey)
From the preliminary definition of these 36 above described indicators of quality, was developed a survey to catch the relevance attributed for the passengers amongst the indicators of quality established by the ACI, and other survey with sights to a local appreciation, searching to soon get an evaluation of the terminal of passengers after the installment of the service.

METHODOLOGY AND APPLICATION
To select the airports for the accomplishment of the location survey, had been observed several considerations amongst which: airports of net INFRAERO of different geographic localizations, two of them in the South Region, one in the Center-West, one in North and two in the Northeast.

For the accomplishment of a more including research it was necessary beyond the support of the FAPESP (Foundation of Support the Research of the State of São Paulo), the support of the DAC (Department of Civil Aviation), with the supply of the air transportation and the support to a researcher auxiliary and support of the INFRAERO, that allowed our presence in its rooms of embarkment during the periods of accomplishment of the survey.

The airports chosen for the accomplishment of the survey had been:

- Salgado Filho International Airport – Porto Alegre-RS (POA);
- Afonso Pena International Airport – Curitiba-PR (CWB);
- Presidente Juscelino Kubitschek International Airport – Brasília-DF (BSB);
- Val de Cans International Airport – Belém-PA (BEL);
- Pinto Martins International Airport – Fortaleza-CE (FOR);
- Luiz Eduardo Magalhães International Airport – Salvador-BA (SSA).

Strategy and application
For the development of the survey strategy, it was considered necessity of if covering, of representative form, all the moments of operation of the terminal. The possible period for application was the month of July of 2002. Positive aspect: it is a period of high movement in the majority of the searched airports. Negative aspect: in some cases it can not represent a period of typical operation and with adjusted perceptions most of its universe of users. They had been adopted, at the very least, 3 days of survey in each airport and carried through collections in the 3 turns: morning, afternoon and night.

The location surveys was initiated in day 07 of July and was finished in 04 of August of 2002, counting on 2 researchers, being carried through in the embarkment room, therefore in this place the passengers already had observed or used the installations and felt the quality of services in the airport installations. This strategy of accomplishment in the embarkment room makes possible that the passengers answer the survey with more tranquillity, therefore already had carried through check-in and is only waiting for the call of entrance in the aircraft. The periods had been selected in accordance with the frequency of the flights in the airports.

Each researcher applied a type of survey, leaving clearly for interviewed the objectives of the same one, being the form filled for the proper interviewer so that it did not have variety in the interpretation of the questions.

Survey instruments
The survey instruments had been developed with the purpose of if identifying the main indicators of quality of the airports and with the purpose of if analyzing and appraising the

installations and services of the airport in question. In survey 1 - General (identification of the main indicators), 22 indicators had been selected to be appraised with: Essential, Desirable and Indifferent. In survey 2 - Local (analysis of the indicators of quality of the airport), 36 indicators had been selected to be appraised in a scale that varied: Very good, Good, Regular, Bad and Very bad. The concepts above attributed had been based on the publication of the ACI.

Results of survey 1 - General
Analyzing the results of survey 1 – General, it is verified that amongst the indicators of the access/parking, the general signalling and the vacant number they had been considered very important being that the variety of transports less important, concluding that the existence of one has carried efficient can be more important that several not efficient.

In the terminal, it is observed that availability of elevators, baggage trolleys, seats and signalling are very important and the distance between installations and esthetic are less important, being able to infer, for these results, that in the terminal the operational areas, have more relevance, probably for dealing with the processing of the passenger involving time, easiness, localization and comfort.

In the essential commercial works, it is observed that all indicators are between the excellent ones, being that the practised prices and quality of the attendance and had make look like more importance that the variety of installations, indicating that the passengers and users look in first place the quality and the prices that the variety of installations.

The information services: availability and attendance, FIDS (Flight Information Display System), the time of processing the cordialidade in check-in and security, had been considered very important, revealing the importance that if must take with these indicators in all the stages of processing.

Finally, in the embarkment room, the availability of seats and services they had been considered essential followed for the esthetic, passing the impression that the passengers search in first place the comfort that properly services and esthetic place.

Table 1, shows the frequency of indication of the concepts in global terms.

Table 1 - frequency of indication of the concepts

concept	% indicators
1 - indifferent	7,07
2 - desirable	35,45
3 - essential	57,48

The results had indicated that none of the indicators can be considered indifferent by the user. But four, amongst the considered ones, had been considered desirable:

In the airport/terminal
- Distance between instalations/components;
- Visual sensation (esthetic).

In the essential commercial services
- variety of installations/services.

In the departure lounge
- Visual sensation (esthetic).

The indicator that was considered by the passengers who travel the businesses as being desirable, but not essential beyond the listed ones above was:

In the essential commercial services
- Practised prices.

Therefore, the quality indicators had been established that are essential and desirable in the airports, according to vision of the passengers.

Results of survey 2 – Local

Index of quality of the airports
An index of the perceived quality of the services and the installations of the airports was gotten calculating it applied weighed mean to the indicators of the airports. With this calculation the weighed mean of the indicators in relation to the concepts of 1 at 5, where 1 corresponds to poor, 2 to the bad, 3 when average, 4 to the good, 5 to the very good.

Table 2, indicates the percentage of the intentions of the trips in the period of survey application.

Table 2 – Intention of the trips

Airport*	Leisure	Business	Other
POA	31,21	65,25	3,55
CWB	16,11	80,54	3,55
BSB	20,71	68,57	10,71
BEL	19,15	78,01	2,84
FOR	46,26	52,38	1,36
SSA	22,70	71,17	6,13

*IATA code (International Air Transportation Association)

In the next Table 3, to follow more frequently displays the weighed mean of the indication

Table 3 – Weighed mean of the indicators

Quality indicators	Airports					
	POA	FOR	BEL	SSA	CWB	BSB
Access/Parking						
general signalling	4,10	4,19	4,10	4,06	4,16	4,14
vacant number	4,03	4,06	4,11	3,91	3,77	3,53
variety of transports	3,64	3,79	3,60	3,84	3,53	3,40
Airport/Terminal						
available areas	4,56	4,41	4,49	4,24	4,27	4,04
distance between instalations/components	4,30	4,10	4,11	3,82	3,97	3,76
availability of elevators/escalators/moving walkways	4,31	4,14	3,91	3,95	3,79	3,78
availability of trolleys	4,41	4,41	4,40	4,37	4,27	4,16
thermal comfort	4,57	4,37	4,33	4,17	3,75	4,23
acoustic comfort	4,47	4,27	4,14	4,21	4,03	3,84
visual sensation (esthetic)	4,68	4,28	4,50	4,28	4,15	3,99
availability/confort of seats	4,34	4,29	4,17	3,53	3,53	3,67
availability of the signaling	4,25	4,18	4,09	4,00	3,99	3,81
availability/cleannes of the sanitary	4,40	4,08	4,43	4,24	4,33	4,19
general security	4,42	4,18	4,06	4,21	4,14	4,01
general cleanliness	4,60	4,36	4,46	4,49	4,42	4,12
general satisfaction/quality of service	4,42	4,29	4,18	4,09	4,05	3,80
Essential commercial services						
practised prices	3,43	3,40	3,43	2,88	3,11	2,79
available areas	4,25	3,79	3,75	2,91	3,63	3,53
quality of the attendance	4,13	4,01	3,94	3,82	3,87	3,73
variety of installations	3,67	3,86	3,72	3,56	3,46	3,41
Information services						
availability of the service	4,22	4,03	3,77	3,85	3,76	3,59
quality of the attendance	4,29	4,09	3,88	3,94	3,13	3,82
System of information FIDS						
FIDS availability	4,24	4,03	3,84	3,91	3,87	3,80
Check-in						
processing time	4,14	4,19	3,99	3,85	3,73	3,70
available area	4,35	4,11	4,16	3,92	3,79	3,80
staff friendliness/attitude	4,49	4,31	4,33	4,16	4,19	4,05
Security Check						
processing time	4,37	4,17	4,16	3,99	4,08	3,94
available area	4,35	4,13	4,19	4,10	3,98	3,87
attendance	4,49	4,27	4,26	4,36	4,19	4,04
Embarkment room						
available services	4,01	4,05	3,84	3,97	3,60	3,63
confort/availability of seats	4,31	4,24	4,03	3,51	3,59	3,53
available area	4,45	4,35	4,39	4,44	3,93	3,85
cleanliness	4,68	4,48	4,52	4,59	4,41	4,15
thermal comfort	4,56	4,29	4,21	4,31	3,85	4,18
acoustic comfort	4,49	4,29	4,18	4,19	4,09	3,83
visual sensation (esthetic)	4,60	4,19	4,41	4,33	4,15	3,99

In the next Table 4, it is observed frequency of distribution of the concepts that indicate the global situation of the quality of services and installations of the airports.

Table 4 – Frequency of distribution of the concepts

| Concepts | Airports | | | | | |
	POA	FOR	BEL	SSA	CWB	BSB
1 - poor	0,87	0,59	0,77	1,05	1,28	1,84
2 - bad	1,82	2,01	3,16	2,98	4,46	7,19
3 - average	9,9	13,03	15,28	15,96	19,8	23,91
4 - good	40,75	47,08	44,12	46,53	45,75	40,70
5 - very good	46,66	36,75	36,38	31,6	27,59	26,35

Graph 1 – Frequency of distribution of the concepts
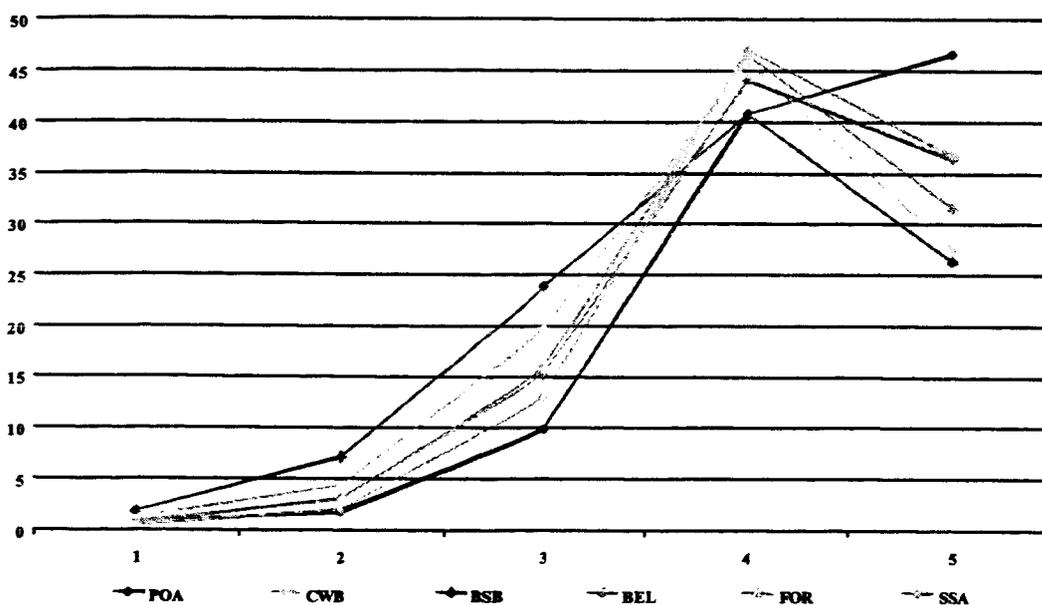
In the previous graph, observes that Brasilia (BSB) presents greaters taxes of indication of concepts poor (1), bad (2) and average (3). Fortaleza (FOR) presents the biggest incidence of good concepts (4), but Porto Alegre (POA) if detaches with the biggest incidence of very good (5) and the minor of the unfavourable index. The results of POA and BSB if show discordant. Still that, excessively they receive a conceptualization relatively similar. Applying the calculation of the weighed mean in the results of table 4, one gets the indices of global quality of the airports displayed in table 5. These index had been gotten being multiplied for 2, the result of the weighed mean, for a scale of 1 at 10.

Table 5 – Index of global quality of the airports

	Airports					
	POA	**FOR**	**BEL**	**SSA**	**CWB**	**BSB**
Index of quality	8,62	8,32	8,22	7,98	7,82	7,66

It can be concluded that in the period of accomplishment of the location survey between the searched airports, the Salgado Filho International Airport, Porto Alegre (POA), is distinguished as most attractive for offering to the best quality of services and the best installations according to its passengers.

CONCLUSIONS

The developed methodology serves as an instrument to evaluate the quality of the installations and services in the airport.

This work is resulted of two years of research that resulted in the master dissertation of the author. The developed methodology made possible that the proper users of the airport installations contributed of direct form in the analysis of the terminals, how much to the installations and offered services making possible, thus, to get the quality indicators that are the essentials, desirable and indifferent in the airport terminals and the analysis of the installations and the quality of the services offered for the searched airports.

The survey had an application limited (in 3 days for airport) for the gotten resources, but, these, had been indispensable for the extend of passengers and airports that was possible to analyze. To get itself resulted still more trustworthy they are indicated to the application of the methodology in at least four months during the period of one year and per seven days of the week, thus making possible to identify to the quality of the installations and services in all the operational scenes of the airports as, hours peak and seasonal.

Finally, the work made possible the validation of plus an aid tool the designers and operators of airports, that they start to make use of a methodology to identify to the characteristics or the aspects that more contribute for the perception of quality of services of the airports for its users, making possible to the professionals to undertake solutions that contribute for a perception greater of quality, making possible after all the greater satisfaction of the customers (passengers) inside of the aeroportuário terminal.

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Route Monopolies and Optimal Nonlinear Pricing

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Abstract

To cope with air traffic growth and congested airports, two solutions are apparent on the supply side: 1) use larger aircraft in the hub and spoke system; or 2) develop new routes through secondary airports. An enlarged route system through secondary airports may increase the proportion of route monopolies in the air transport market.The monopoly optimal non linear pricing policy is well known in the case of one dimension (one instrument, one characteristic) but not in the case of several dimensions. This paper explores the robustness of the one dimensional screening model with respect to increasing the number of instruments and the number of characteristics. The objective of this paper is then to link and fil the gap in both literatures. One of the merits of the screening model has been to show that a great variety of economic questions (non linear pricing, product line choice, auction design, income taxation, regulation...) could be handled within the same framework.We study a case of non linear pricing (2 instruments (2 routes on which the airline provides customers with services), 2 characteristics (demand of services on these routes) and two values per characteristic (low and high demand of services on these routes)) and we show that none of the conclusions of the one dimensional analysis remain valid. In particular, upward incentive compatibility constraint may be binding at the optimum. As a consequence, they may be distortion at the top of the distribution. In addition to this, we show that the optimal solution often requires a kind of form of bundling, we explain explicitly distortions and show that it is sometimes optimal for the monopolist to only produce one good (instead of two) or to exclude some buyers from the market. Actually, this means that the monopolist cannot fully apply his monopoly power and is better off selling both goods independently.We then define all the possible solutions in the case of a quadratic cost function for a uniform distribution of agent types and explain the implications for airlines in terms of service diffenrentiation.

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1   Introduction

To cope with air traffic growth and congested airports, two solutions are apparent on the supply side: 1) use larger aircraft in the hub and spoke system; or 2) develop new routes through secondary airports. An enlarged route system through secondary airports may increase the proportion of route monopolies in the air transport market. Other solutions exist (slot auctions for example) are out of the scope of this paper (see for example, M Raffarin (2003)).

Because large aircraft took years to develop, required enormous up-front investment and has useful lives of more than 30 years, Airbus and Boeing had to generate long-term demand projections. To do so, they prepared 20-year forecasts for large commercial aircraft: Airbus published its Global Market Forecast (GMF hereafter) while Boeing published its Current Market Outlook (CMO hereafter). Eventhough these forecasts are produced according to 2 different models, both manufacturers agreed that there would be a significant growth in the air transportation industry (worldwide passenger traffic will almost triple by 2019; Airbus forecast an average annual growth rate of 4.9% while Boeing estimates an average growth rate of 4.8%). They also agreed that Asia would register the world's highest growth rates over the next 20 years (See Ref 1).

To produce GMF, Airbus predicted annual demand for new aircraft on each of the 10000 passenger routes linking almost 2000 airports assuming that passenger and cargo demand would track the Growth Domestic Product (GDP hereafter) growth as they had over the past 50 years. For each airline, on each route pair, the model estimated the need for specific aircraft and compared that number against the then existing supply of aircraft. The model calculated maximum feasible frequency limits for each route based on assumptions about airport capacity, airplane speed, distance and some other factors. It assumed that airlines would attempt to keep their market share by adding capacity as demand increased and by increasing aircraft size when it was no longer feasible to increase flight frequencies. Airbus forecast demand for 14661 new passenger aircraft and 703 new are freighter over the next 20-year period by 2019. It forecast demand for 727 new aircraft seating from 400 to 500 passengers (the mainstay of the 747 market) and 1550 new aircraft seating more than 500 passengers (1235 passenger aircraft and 315 cargo aircraft). The GMF also predicted that by 2019 , Asia-Pacific airlines would hold half of the very large aircraft (VLA hereafter) passenger fleet and that 6 of the top 10 airports served by VLA would be in Asia (See Ref 1).

In contrast, Boeing forecast economic growth in 12 regions in its CMO. It then used these growth assumptions to forecast regional traffic flows in 51 intra- and inter-regional markets. For example, travel within China would grow at an average annual rate of 9% compared to 2.8% in North America. The CMO concluded there would be demand for 22315 new aircraft through 2019. One reason for this difference between the two forecasts was that the CMO included for more than 4000 regional jets. Despite general agreement on overall growth, Boeing forecast a much smaller VLA market. The CMO stated bluntly: "The demand for VLA is small" (See Ref 2). It forecast total demand for only 1010 new aircraft seating 400 passengers or more, 40% of which would be 747-400's (410 new aircraft). Of the remaining 600 planes, 270 would be cargo planes, leaving demand for only 330 aircraft seating 500 passengers or more. More importantly, most of the demand for the larger planes would not materialize for at least 10 years (See Ref 2).

The disparity between these two forecasts could be traced to conflicting assumptions regarding the relative importance of flight frequency, new route development and aircraft size. Airbus believed that increased flight frequencies and new routes would provide only short term solutions

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to the problem of growing demand. Airport curfews, gate and runaway capacity and passenger arrival preferences would limit the ability to increase flight frequencies at many airports including some of the world's busiest airports like London Heathrow, Tokyo Narito, Singapore and LA International. As Airbus EVP John Leahy said "the trouble is that on these long distance flights, nobody wants to arrive at 3.00AM and nobody wants to drive at the airport for a 2.30AM departure so that they can have more flights" (See Ref 3). At the same time Airbus did not believe that development of new routes would provide a long term solution. Adam Brown, VP for strategic planning and Forecasting, noted "the pace of new route development has slowed sharply...between 1990 and 1995, the total number of route grew by less than 700, an average increase of 1.7% per year. Part of the problem was the difficulty of opening new airports. In fact, only 10 major airports where scheduled to open within the next 10 years and only 18 airports had approved plans to grow (See Ref 3). An even bigger concern was the fact that new routes would not solve the problem of growth at largest population centers, especially in Asia. While Boeing and others cited the expansion of new routes in transatlantic markets as a model for growth in transpacific travel, Airbus pointed out that Asia lacked secondary urban centers to support new destinations(See Ref 4). Thus, hub-to-hub transport would remain the industry standard in these markets.

Like Airbus, Boeing assumed that increasing flight frequency at existing airports would absorb certain amount of growth, but that congestion at the largest hubs would require an alternative solution, which according to Boeing would be new point-to-point routes using medium sized, long-range aircraft like 777 or 340. In support of this view, a Boeing executive claimed "...60% of the airlines bought 1000 or so 747s we've sold bought them for their range, not for their capacity" (See Ref 5). To the extent, there was demand for VLA, the 747-400 would be sufficient for most airlines.

Recent development in the airline industry supported this assertion. In the USA, following airline deregulation in 1985, southwest airlines had prospered by introducing new services at secondary airports such as Providence, Rhode Island and Islip, NY. In Europe Ireland based Ryanair was copying Southwest's model and had achieved 25% annual passenger growth since 1989 by offering no-frills, economy service between secondary airports (See Ref 6). More recently start-ups and buzz and easyjet had adopted similar business models. Transatlantic and to a much lesser extent transpacific travel reflected this trend towards segmentation. Randy Base, a Boeing Vice President explained "back in 1987, the only daily flight between Chicago and Europe was a TWA to London. In those days, 60% of American carriers' transatlantic flights were in 747s operated by Pan Am and TWA in and out of big East cost airports. In 2000, United and American Airlines were operating from Chicago to 11 European destinations using smaller 767 and 777 aircraft (See Ref 7). More recently, both Delta Airlines and American Airlines had introduced new point-to-point service across the Pacific, the former from Portland, Oregon , to Nagoya, Japan and the latter from San Jose, California, to Tokyo (See Ref 8). Related to the opening of new routes was a decline in the average seating capacity in many airline fleets. In fact, Boeing predicted that smaller jets such as its 777 or Airbus A330 would provide 160 fragmentation across the Pacific(See Ref 7). Boeing assumed these trends would continue because people seemed to favor timely and direct service over minimum cost as they became wealthier (See Ref 2). Another factor would contribute to further fragmentation, though one that was exceedingly difficult to predict, was entry by new airlines. Nevertheless Boeing

believed entry was likely.

Industry analysts made projections that felt somewhere in between the two. The Airline Monitor, a leading industry journal, assumed that airlines would buy the A380 for its operating advantages and passenger appeal. Based on this assumption, the journal forecast total demand for 735 A380 through 2019 (including Cargo planes) (See Ref 9). It is also predicted that the hub-and-spoke system will remain the industry standard. Even if, new routes development through secondary airports will not solve entirely the air traffic growth and congested airports issues, it will enable airlines to lower their cost (low airport fees, city-, region- or government-support...) and at the same time to have monopoly positions on these routes allowing positive profits (if there is enough demand of course).

This paper does not intend to show that Airbus's or Boeing's predictions are right or false. The above comments show that the hub-and-spoke system will remain the industry standard and also that new route development through secondary airports will be one of the key feature of the 21st century air transport industry. Assuming the above statement, new route development through secondary airports will also give birth to route monopolies (as it is often the case for low cost airlines). In addition to being new market shares for airlines, these new point-to-point services through secondary airports will also enable airlines, at least for a certain period of time, to have monopoly positions on these routes and as a consequence, to make positive profits. We assume monopolistic positions for the carrier as the products (point-to-point routes) are so differentiated from the other products of the market (routes through the hub-and spoke system) that they are assume to be different. Example: direct flight from Toulouse (France) to Vancouver (Canada) is different from flying from Toulouse to Amsterdam, then from Amsterdam to Seattle and then from Seattle to Vancouver.

The objective of this paper is to study the optimal pricing policy of a monopolist facing a population of heterogenous buyers. In the air transport literature, on the one hand, after airline industry deregulation, pricing policy in the hub-and-spoke system, airport dominance (...) has been largely reviewed (for examples, Graham et al. (1983), Berry (1990), Borenstein (1989, 1990), Bruekner et al. (1992)) but on the other hand, the monopolist's optimal pricing policy has been put aside even if 60% of the routes in the world are operated through a monopolistic position. In Economics, the analysis of optimal screening has been subject of a large literature, partly justified by the great variety of contexts to which such an analysis can be applied: non linear pricing, product lines design, optimal taxation, regulations, auctions. Although it is often recognized that agents have several characteristics and principal have several instruments, this problem is often studied under the assumption of a unique characteristic and a unique instrument. The case of several characteristics and several instruments has been studied and the qualitative features of the optimal pricing policy have been established (Wilson (1993), Armstrong (1996), Rochet-Choné (1998). Nevertheless, only few examples were solved (Wilson (1993), Rochet (1995)).

The objective of this paper is to link and fill the gap in both literatures. This paper studies the optimal pricing policy of a monopolist (airline) who produces two goods (operates 2 routes) and faces a heterogenous population of buyers. The buyers (travel agencies) have two characteristics (one for each good), two possible values per characteristic and therefore four possible types of buyer. After a brief survey in section 2, where we recall the qualitative features of the solution to the monopolist's problem where agents are represented by a single characteristic and the

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principal has only one instrument, section 3 focuses on the specific problem of non linear pricing by a monopolist in the simplest possible multidimensional model. Section 4 gives the solution and shows that results obtain in one-dimension model are not robust to increases in numbers of characteristics and instruments (some upward incentive compatibility constraints are binding at the optimum). For example, it is sometimes optimal for the airline to provide services above the first best level to some of its customers. Section 5 studies the problem in a different but equivalent way and enables to explain distortions in resource allocations. Section 5 studies the general solutions and section 6 defines several sets of solutions and implications for airline in terms of service differentiation. Section 7 concludes.

2 A brief Survey

2.1 Airline pricing policy

Airline deregulation has led to profound changes in the structure of the industry. In addition to giving airlines the freedom to set fares, deregulation removed restrictions on entry and exit, allowing the carriers to expand and rationalize their route structures. This flexibility led in the 1980s to a dramatic expansion of hub-and-spoke networks, where passengers change planes at a hub airport on the way to their eventual destination. By funneling all passengers into a hub, such a system generates high traffic densities on its "spoke" routes. This allows the airline to exploit economies of density, yielding lower cost per passenger. These economies arise partly because high traffic density on a route allows the airline to use larger and more efficient aircraft and to operate this equipment more intensively (at a higher load factor).

Restructuring of the industry in response to deregulation has also led to renewed interest among economists in the determinants of airfares in individual city-pair markets. This line of research contains notable contributions by Graham-Kaplan-Sibley (1983), Borenstein (1989), Morisson-Winston (1990). These studies typically explore the connection between airfares and market-specific measures of demand (city populations and incomes, tourism potential...), cost (flight distance, load factors...)and competition (number of competitors, market share...) without paying much attention to network characteristics. Bruekner et al. (1992) shows the impact of network characteristics in airfares determination by providing first evidence linking airfares to the structure of airline hub-and-spoke networks. When a hub-and-spoke successfully raises traffic density, ticket prices are likely to reflect the resulting lower cost per passenger. Any force that increases the traffic volume on the spokes of a network will reduce fares in the market it serves. This effect arises because of economies of density on the spokes. For example, since a large network (as measured by the number of city pairs it connects) offers many potential destinations to the residents of an endpoint city, its spoke should have higher traffic densities than the spokes of a smaller network. With costs correspondingly lower, fares in the individual markets served should be lower in the large network, other things equal. Similarly, holding size fixed, a network that connects large cities should have higher traffic densities on its spoke (and thus lower fares in individual markets) than one serving small cities.

The case of fare determination in the case of route monopolies has received little attention. With these hard times and cut-throat competition in the hub-and-spoke system, this could be serious omission.

In addition to being new markets shares for airlines, new routes through secondary airports

(secondary population centers), point-to-point service, can also be seen as a business model. "Low cost" airlines often use this model. Under the "low cost" label, we can easily say that these carriers have monopolistic position on some routes (Ryanair in Europe, SouthWest in the United States of America for examples). Even if they are "low cost" airlines and are able to provide low fare tickets, this does not means that do not use their monopoly on their market niches (they probably do to reach such operating margin). What we propose in this paper is to assume that an airline may have incentives to use a part of the "low cost" business model (secondary airports) but on another business model. Thanks to low "airport costs", point-to-point service the airline is able to propose attractive prices and also to apply its monopoly power on its market niche. Moreover, the airline may also be supported by cities, regions, or governments for the impact of a route opening on the economic development of a population center. To do so, we assume that there exists city pairs, population centers where the macro-economic environment allows an airline to operate successfully a new route. Instead of providing customers with single class flights, the airline proposes several levels of services (economy, business and first for example) to apply price discrimination through its monopoly power. If an airline can operate one route on such a city pair, the optimal non linear pricing policy is described in section as the one-dimension case. If an airline can operate two routes on two such city pairs or through three population centers, the optimal pricing policy is described and explained in the remaining part of the paper.

2.2 Mechanism design and non linear pricing

The analysis of optimal screening has been the subject of a large literature, partly justified by the great variety of contexts to which such an analysis can be applied: nonlinear pricing, product lines design, optimal taxation, regulation, auctions...

Although it is often recognized that agents have several characteristics and principals have several instruments, this problem is often studied under the assumption of a unique characteristic and a unique instrument. In this case we obtain the following results:

- the set of self selection constraints that are binding at the optimum is typically the same: the Individual Rationality Constraints (IRC hereafter) at the lower extreme of the distribution of types, and downward local Incentive Compatibility Constraints (ICC hereafter) everywhere.

- we decompose the problem in two parts: first, find the system of transfers that minimizes the expected informational rent for a given allocation of goods; second, find the allocation of goods that maximizes the profit of the principal.

- because of the informational rent, second best allocation is distorted below, except at the upper extreme of the distribution of types where it coincides with the first best allocation.

Considering the multiplicity of characteristics and instruments in most applications, it is important to know if those results are still valid in the multidimensional context.
In the screening literature, the question has been essentially considered in two polar cases:

- one instrument-several characteristics: in this case, it is impossible to obtain perfect screening among agents. The same level of the instrument is chosen by many different agents

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(in Lewis-Sappington (88), this corresponds to firms having different costs and demands). However Laffont-Maskin-Rochet (87) and Lewis-Sappington (88) show it is possible to aggregate these types and reason in terms of the average cost function of all firms having chosen the same level of production. Nevertheless, several qualitative properties persist: for instance, Lewis-Sappington (88) show that price exceeds expected marginal cost, except at the top of the distribution where they are equal.

- several instruments-one characteristic: the situation is very different. Matthews-Moore (87) extend the Mussa-Rosen's model by allowing the monopolist to offer different levels of warranties as well as qualities. One of their most striking result is that the allocation of qualities is not necessarily monotonic with respect to types. As a consequence, non local ICC may be binding at the optimum.

The most interesting case is the one with several characteristics and several instruments, because it is the most realistic but also the most difficult.

Seade (79) has studied the optimal taxation problem for multidimensional consumers and has shown that it was equivalent to a variation calculus problem with several variables. McAfee-McMillan (88) make a decisive step in the study of monopoly pricing under multidimensional uncertainty. They introduce a General Single Crossing Condition under which ICC can be replaced by the local conditions of the agents' decision problems. They also show that the optimal screening mechanism can be obtained as the solution of a variations calculus problem. In 92, Armstrong provides a very clear treatment of the difficulties involved in the multidimensional extension of the Mussa-Rosen's problem of optimal product lines design by a monopolist. Wilson (93) contains a very original and almost exhaustive treatment of nonlinear pricing models: several multidimensional examples are solved.

Focus can now be made on bidimensional problems: Rochet (84) studies an extension of Baron-Myerson regulation problem in a bidimensional context where both marginal and fixed costs are unknown to the regulator. Contrarily to Lewis-Sappington, Rochet allows for stochastic mechanisms (as Baron-Myerson did): this provides a second instrument to the regulator. On a particular example, Rochet (84) shows that the optimal mechanism can indeed be stochastic, as conjectured by Baron-Myerson. Following Spence's early(80) and deep contribution, Dana (93) gives in a different context a partial solution of the discrete screening model with two types and two attributes, and finds two solutions depending on the correlation of types' characteristics. Armstrong-Rochet (98) study a bidimensional screening model in which four types of agents, who are discretely distributed, can undertake two kinds of activities. Each activity can be undertaken at a high or low level. They consider two ways to solve the problem:

- The relaxed problem: they only consider the five downward ICC. They show that three types of solution can occur (cases C and D are in fact identical if one permutes activity A and B). Those solutions change according to the correlation between activities. The binding constraints are in those cases are the IRC of the lowest type and a set of downward ICC. The highest type always gets his first allocation and there is no distortion at the top. This can be explained by the considered ICC: when only downward ICC are considered, rents do not depend on the high type activity levels and therefore do not need to be distorted.

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- The fully constrained problem: they consider the whole set of ICC. This gives rise to a fourth solution (actually there are two, but they are symmetric): one upward ICC and the transverse ICC are binding. As a consequence, an "intermediary type" gets his first best allocation and the highest gets an allocation above the first best level.

2.3 A Brief Recall of the Unidimensional Case

Consider an economy in which a monopolist, an airline, sells his production (travel on this route) to a heterogenous population of two types ($t = \{t^l, t^h\}$), customers having low (l) or high (h) demand of services on this route, who are represented in proportion π^l and π^h ($\pi^l + \pi^h = 1$). As the airline operates through secondary airports, it can lower its airport fees and thus proposes point-to-point service, attractive prices and can fully apply its monopoly power. The monopolist wants to maximize his profit:

$$max_q \sum_i [p^i q^i - c(q^i)],$$

$$= max_q \sum_i [u^i(t, q) - U^i(t, q) - C(q^i)],$$

where $u^i(t^i, q^i) = t^i q^i$ and $U^i(t^i, q^i) = u(t^i, q^i) - p^i q^i$. This maximization problem is subject to the Individual Rationality and the Incentive Compatibility constraints:

$$IRC : U(t^i, q^i) \geq 0,$$
$$ICC : U(t^i, q^i) - U(t^i, q^j) \geq u(t^i, q^j) - u(t^j, q^j).$$

We then obtain:

$$U^l = u(t^l, q^l) - p^l q^l,$$
$$U^h - U^l = (t^h - t^l) q^l,$$
$$U^l - U^h > (t^l - t^h) q^h.$$

As a consequence buyers of type h get their first best allocation whereas types l receive a downward distorted allocation.

Writing the Lagrangian and computing the solution gives:

$$L = \sum_i [u^i(t, q) - U^i(t, q) - C(q^i)] - \sum_{i,j} \mu_{ij}(U(t^i, q^i) - U(t^i, q^j) - u(t^i, q^j) + u(t^j, q^j))$$
$$- \sum_i \lambda^i U^i.$$

The first order conditions give:

$$\lambda^l = -1,$$
$$\mu_{hl} = -\pi^h,$$
$$p^l = C'(q^l) + \frac{\pi^h}{\pi^l}(t^h - t^l),$$
$$p^h = C'(q^h).$$

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This means that the airline is able to find the optimal pricing mechanism and service allocation that enables its profit maximization. Customers with high demand of services will receive their first best allocation (price equals marginal cost) whereas customers with low demand of services will receive a downward distorted allocation of services (below the first best level of course). Airlines provide services below the first best level on low fare tickets to give incentives to customers with high demand of services to buy high fare tickets instead of buying low fare tickets. They just propose "minimum" services to "poor customers" and offer "superfluity" to "rich travellers".

Focus can now be made on the bidimensional case.

3   Statement of the Problem

We focus here on the specific problem of nonlinear pricing by a monopolist in the simplest possible model (two characteristics, two possible values per characteristic and therefore four possible types), and first give the solution which has the same qualitative features than in dimension one, in the case of a linear quadratic cost function(in a previous version of his paper with Choné, Rochet (95), alone, studies this problem, where production is a level of quality, and we study the case of quantity with a non zero cross cost) whereas Armstrong-Rochet (98) study the case of constant marginal costs. Such a solution appears when the correlation between characteristics is near zero and the cross cost parameter is not too big: in such a case, only downward local ICC and IRC of the lowest type are binding but according to the value of the cross cost parameter, the quantities can be distorted downwards or upwards. This differs from dimension one (except when there is no cross cost parameter) and the highest type receives his first best allocation of goods. We call it the regular case. Matthews and Moore (87) study a standard model (Mussa-Rosen (78)), taking three types into account, the IRC is only effective for type 3. In this case type 1 faces undistorted quality while the other two receive degraded quality (unidirectional downward distortion), but allocations are not monotonic. In Donnenfeld-White (88) there is unidirectional upward distortion. But Srinagesh-Bradburg (89) find bidirectional distortions(one upwards, one downwards). We then define the complete solution in three different situations, first, where there is no cross cost and a discrete uniform distribution of types, where we obtain the same four solutions as in Rochet (95), second, where there is no cross cost and a general discrete distribution of types and also in the case of a discrete uniform distribution, with a non zero cross cost parameter, where we obtain ten other solutions.

3.1   The Model

We consider a natural bidimensional extension of the Mussa-Rosen's (1978) model, in which a multiproduct monopolist sells two goods to a heterogenous population of four types of discretely distributed buyers. The model is different from Mussa-Rosen's because production represents quantities and not qualities. The airline operates two routes, route 1 and route 2 and provides her customers with quantities of services on route 1, q_1, and on route 2, q_2. Customers are characterized by their type, $t = (t_1, t_2)$, their demand for services on route 1 and 2 (distance, departure time, arrival time, number of possible changes, on-board space, ...).

Buyers utilities are quasilinear:

$$U^i = u(t^i, q_1, q_2) - p(q_1, q_2) - E,$$
$$u(t^i, q_1, q_2) = t_1^i q_1^i + t_2^i q_2^i,$$
$$p^i q^i = p_1^i q_1^i + p_2^i q_2^i,$$

where t^i is a bidimensional vector of characteristics of the consumers (his type), q is a bidimensional vector of the quantities of the goods and p is the unit price of the goods. $u(t, q)$ represents the monetary equivalent of the goods, with characteristic vector q for a consumer of type t.

Notice that q and t have the same dimensionality so that perfect screening (in the sense that consumers with different types always buy different quantities of goods) is possible, i.e., we assume that the (full information) optimal resource allocation $\hat{q}(\cdot)$ involves perfect screening. $\hat{q}(\cdot)$ is defined as follows:

$\forall t \in T$, $\hat{q}(t) = \arg\max_q [S(t, q)]$,

where $S(t, q) = u(t, q) - C(q)$, and T represents the set of possible types and $C(q)$ is the cost function of the monopolist:

$$C(q_1, q_2) = \frac{1}{2}(q_1^2 + q_2^2) + \rho q_1 q_2.$$

We use such a cost function, as we assume that for a low quantity of services, the necessary services are served first (the flight itself) and as the number of services increases, the services become more and more superfluous and as a consequence, more and expansive. ρ is used for positive or negative production synergies. We also assume that the surplus function $S(t, q)$ is strictly concave, differentiable in q and has, for all t, a unique maximum $\hat{q}(t)$. The set of $\hat{q}(\cdot)$ will be used as a benchmark for evaluating the distortions of resource allocations entailed by the monopoly power under bidimensional adverse selection.

3.2 The Monopolist's Problem

We describe the strategy of the monopolist as a set of price-quantity allocations (p^i, q^i) satisfying *ICC* and *IRC* :

IR:$U^i \geq 0$, for all i,

IC: $u(t^i, q^i) - p^i q^i - E^i \geq u(t^i, q^j) - p^j q^j - E^j$, for all i, j.

The airline has to define the price of a ticket and the associated quantity of services for each type of agent that satisfy his or her *IRC* and the *ICC*.

They are equivalent to:

IR:$U^i \geq 0$,

IC: $U^i - U^j \geq u(t^i, q^j) - u(t^j, q^j)$.

Finally, π^i denotes for all i the proportion of agents of type i in the population of potential buyers. The monopolist's optimal strategy is obtained by maximizing his profit:

$Max \sum_i \pi^i (p^i q^i - C(q^i) + E^i)$,

which is equivalent to:

$Max \sum_i \pi^i (u(t^i, q^i) - U^i - C(q^i))$ under the above constraints.

Note: we write this expected profit as:

$$Max \sum_i \pi^i (p^i q^i - C(q^i) + E^i),$$

instead of the commonly used expression:

$$Max \sum_i \pi^i(p^iq^i + E^i) - C(\sum_i q^i).$$

We choose the first formulation because $C(q)$ is convex. As a consequence, $C(\sum_i q^i) \geq \sum_i C(q^i)$. With a technology that generates such a cost function, it is less costly for the monopolist to use "just in time production" and to maximize profit as previously mentioned. This is the case for services.

There are two characteristics and two possible values for each characteristic. Therefore there are four possible types of consumers . We denote these types by letter $i = A, B, C, D$.

$$\begin{aligned}
t^A &= (t_1^l, t_2^l), & (\pi^A), \\
t^B &= (t_1^h, t_2^l), & (\pi^B), \\
t^C &= (t_1^h, t_2^h), & (\pi^C), \\
t^D &= (t_1^l, t_2^h), & (\pi^D).
\end{aligned}$$

To avoid symmetric problem and to better differentiate B and D, we assume:

$$(t_1^h - t_1^l)\pi^B \geq (t_2^h - t_2^l)\pi^D,$$

which means for example that route 2 is shorter that route 1.

The specified a quadratic cost function is:

$$C(q_1, q_2) = \frac{1}{2}(q_1^2 + q_2^2) + \rho q_1 q_2, \quad \rho \in \;]-1, 1[.$$

This implies that $\hat{q}$ is linear:

$\hat{q}(t_1, t_2) = (\frac{t_1 - \rho t_2}{1 - \rho^2}, \frac{t_2 - \rho t_1}{1 - \rho^2})$.

The Lagrangian of the problem :

$L(U, q) = \sum_i \pi^i(u(t^i, q^i) - U^i - C(q^i)) - \sum_{i,j} \mu_{ij}(U^i - U^j - u(t^i, q^j) + u(t^j, q^j)) - \sum_i \lambda^i U^i$

where μ_{ij} and λ^i represent respectively the (non positive) multipliers associated to $ICC(i, j)$ and $IRC(i)$. The first order conditions (which are necessary and sufficient for the linear program) give:$\forall i, \delta L/\delta U^i = -\pi^i - \sum_j(\mu_{ij} - \mu_{ji}) - \lambda^i = 0$,

$\leftrightarrow \pi^i + \lambda^i = \sum_j(\mu_{ji} - \mu_{ij})$ and adding these equations on i gives:

$\sum_i \pi^i = -\sum \lambda^i = 1$,

$\leftrightarrow \forall i, \pi^i \leq \sum_j(\mu_{ji} - \mu_{ij})$, with = if $U^i > 0$ (equivalent to $\lambda^i = 0$).

This is equivalent to say that at least for one i, the IRC is binding. This is economically clear since adding a uniform fee to a price schedule does not alter ICC, and increases the monopolist's profit.

Following Border-Sobel (87), we say that j attracts i when $IC(ij)$ is binding. These relations (who attracts whom?) are crucial for determining distortions in resource allocation. Therefore if i attracts no one ($\mu_{ij} = 0, \forall j$), i receives his first best allocation.

When $U^i > 0$: $\pi^i = \sum_j(\mu_{ji} - \mu_{ij})$. This condition explains the trade off faced by the monopolist in the choice of unit price p^i, price paid by types t^i. A small increase for p^i to $p^i + \epsilon$

has a direct effect on profit: it increases it by $\epsilon\pi^i$ per unit, where π^i is the proportion of types t^i. However this marginal increase also has a complex, indirect effect on profit: for all js who are attracted by i ($-\mu_{ji} > 0$), prices have to be decreased by ϵ, otherwise $IC(ij)$ would no longer be satisfied anymore, which decreases the profit per unit by $\epsilon\mu_{ij}$. Symmetrically, for all js such that i is attracted to j ($\mu_{ij} < 0$) prices can be increased by ϵ so that $IC(ij)$ still binds. This increases the profit per unit by $-\epsilon\mu_{ij}$. This condition shows that these effects are exactly compensated when prices are optimally chosen.

4   The Solution (1)

To solve the problem, the question is to guess what constraints are binding and then check that is indeed the case. Intuitively for t^l large enough (the lowest level of service that the airline offers is the travel itself) and ρ not too big, all quantities served will be strictly positive, which implies that $IR(A)$ will be the IRC that binds. In this case:
$\forall i \neq A, \pi^i = \sum_j (\mu_{ji} - \mu_{ij})$.

4.1   The regular symmetric case

By analogy with the one dimensional case, it is tempting to assume that only downward or leftward ICC will be binding. This is what we call the Regular Case (Regular because only downward or leftward ICC can be binding). If, moreover, all such constraints are binding, we obtain what we call the Regular Symmetric Case, represented on diagram 1 (see diagram 1), where an arrow between i and j means that $IC(i,j)$ is binding (j attracts i), and a circle around point i means that $IR(i)$ is binding ($U^i = 0$).

We assume now that: $\Delta t_1 \pi^B > \Delta t_2 \pi^D$. This assumption allows to better differentiate the market of good 1 from the market of good 2.

We look for the regular symmetric solution of the monopolist's problem.

Applying the first order conditions, we get:

$$\mu_{BA} + \mu_{DA} = \pi^A - 1, \quad (\lambda^A = -1)$$
$$-\mu_{BA} + \mu_{CB} = \pi^B,$$
$$-\mu_{CB} - \mu_{CD} = \pi^C,$$
$$\mu_{CD} - \mu_{DA} = \pi^D,$$

and the other Lagrange multipliers are equal to 0.

We then obtain the optimal quantities (substituting q_1^i in q_2^i and vice and versa) as functions of μ_{BA}:

$$q_1^A = \frac{1}{(1-\rho^2)}[t_1^A + \Delta t_1 \frac{\mu_{BA}}{\pi^A} - \rho(t_2^A + \Delta t_2 \frac{(\pi^A-1-\mu_{BA})}{\pi^A})],$$

$$q_1^B = \frac{1}{(1-\rho^2)}[t_1^B - \rho(t_2^B + \Delta t_2 \frac{(\pi^B+\mu_{BA})}{\pi^B})],$$

$$q_1^C = \frac{1}{(1-\rho^2)}[t_1^C - \rho(t_2^C)],$$

$$q_1^D = \frac{1}{(1-\rho^2)}[t_1^D + \Delta t_1 \frac{(-\mu_{BA}-\pi^B-\pi^C)}{\pi^D} - \rho(t_2^D)],$$

$$q_2^A = \frac{1}{(1-\rho^2)}[t_2^A + \Delta t_2 \frac{(\pi^A-1-\mu_{BA})}{\pi^A} - \rho(t_1^A + \Delta t_1 \frac{(\mu_{BA})}{\pi^A})],$$

$$q_2^B = \frac{1}{(1-\rho^2)}[t_2^B + \Delta t_2 \frac{(\pi^B+\mu_{BA})}{\pi^B} - \rho(t_1^B)],$$

$$q_2^C = \frac{1}{(1-\rho^2)}[t_2^C - \rho(t_1^C)],$$

$$q_2^D = \frac{1}{(1-\rho^2)}[t_2^D - \rho(t_1^D + \Delta t_1 \frac{(-\mu_{BA}-\pi^B-\pi^C)}{\pi^D})].$$

In this case, agents utilities are:

$$U^A = 0,$$
$$U^B = \Delta t_1 q_1^A,$$
$$U^D = \Delta t_2 q_2^A,$$
$$U^C = \Delta t_1 q_1^A + \Delta t_2 q_2^B = \Delta t_1 q_1^D + \Delta t_2 q_2^A,$$

where $\Delta t_i = t_i^h - t_i^l$.

We have 4 unknowns (μ_{ij}s) and 3 equations. The missing equation is obtained by examining diagram 1. The difference of utility between C and A can be computed along two paths (through B or through D):

$$U^C - U^A = \Delta t_1 q_1^A + \Delta t_2 q_2^B = \Delta t_1 q_1^D + \Delta t_2 q_2^A.$$

Replacing the expressions of q^is in the above equation and solving the system of four equations with four unknowns, we obtain:

$$\mu_{BA} = -\frac{[\Delta t_1^2((\pi^B+\pi^C)/\pi^D) + \Delta t_2^2(1/\pi^A) - \rho \Delta t_1 \Delta t_2((\pi^A-1)/\pi^A)]}{[((1/\pi^A)+(1/\pi^D))\Delta t_1^2 + ((1/\pi^A)+(1/\pi^B))\Delta t_2^2 + 2\rho \Delta t_1 \Delta t_2/\pi^A]}.$$

This defines a solution for the problem only if all μ_{ij}s are non positive, which is equivalent to:

RSC0:$\mu_{BA} \leq -\pi^B$

$\Leftrightarrow \pi^A \pi^C - \pi^B \pi^D \geq \frac{-\Delta t_2^2(\pi^D(\pi^C+\pi^D))+\rho\pi^D(1-\pi^A-2\pi^B)\Delta t_1 \Delta t_2}{\Delta t_1^2}$

RSC1:$\mu_{BA} \geq -\pi^B - \pi^C$

$\Leftrightarrow \pi^A \pi^C - \pi^B \pi^D \geq \frac{-\Delta t_1^2(\pi^B(\pi^C+\pi^B))+\rho\pi^B(1-\pi^A-2\pi^B-2\pi^C)\Delta t_1 \Delta t_2}{\Delta t_2^2}$

We then look for the other conditions that must be checked by the parameters of the model for the RSC to be solution (see appendix 1) and we obtain conditions on q_α^is and μ_{ij}s.

These conditions can be written as functions of μ_{BA}:

RSC0:$\mu_{BA} \leq -\pi^B$,

RSC1:$\mu_{BA} \geq -\pi^B - \pi^C$,

RSC2:$q_1^A \leq q_1^D$,

$\hookrightarrow \mu_{BA}[-\Delta t_1(\frac{\pi^A+\pi^D}{\pi^A\pi^D}) - \rho\frac{\Delta t_2}{\pi^A}] - \rho\frac{\Delta t_2}{\pi^A} - \Delta t_1(\frac{\pi^B+\pi^C}{\pi^D}) \geq 0.$

RSC3:$q_1^D \leq q_1^B$,

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$\hookrightarrow \mu_{BA}[\frac{\Delta t_1}{\pi^D} - \rho\frac{\Delta t_2}{\pi^B}] + \frac{\Delta t_1(1-\pi^A)}{\pi^D} \geq 0.$

RSC4:$q_1^A \leq q_1^B$,

$\hookrightarrow \mu_{BA}[-\frac{\Delta t_1}{\pi^A} - \rho\Delta t_2(\frac{\pi^A+\pi^B}{\pi^A\pi^B})] + \Delta t_1 - \rho\frac{\Delta t_2}{\pi^A} \geq 0.$

RSC5:$q_2^A \leq q_2^B$,

$\hookrightarrow \mu_{BA}[\Delta t_2(\frac{\pi^A+\pi^B}{\pi^A\pi^B}) + \rho\frac{\Delta t_1}{\pi^A}] + \frac{\Delta t_2}{\pi^A} - \rho\Delta t_1 \geq 0.$

RSC6:$q_2^B \leq q_2^D$,

$\hookrightarrow \mu_{BA}[-\frac{\Delta t_2}{\pi^B} + \rho\frac{\Delta t_1}{\pi^D}] + \rho\frac{\Delta t_1(1-\pi^A)}{\pi^D} \geq 0.$

RSC7:$q_2^A \leq q_2^D$,

$\hookrightarrow \mu_{BA}[\frac{\Delta t_2}{\pi^A} + \rho\Delta t_1(\frac{\pi^A+\pi^D}{\pi^A\pi^D})] + \frac{\Delta t_2}{\pi^A} + \rho\frac{\Delta t_1(\pi^B+\pi^C)}{\pi^D} \geq 0.$

RSC8:$q_2^B \leq q_2^C$,

$\hookrightarrow \mu_{BA} \leq 0.$

RSC9:$q_1^D \leq q_1^C$,

$\hookrightarrow \mu_{BA} + 1 - \pi^A \geq 0.$

For $\varrho = 0$, notice that the solution exists only when:

$(\pi^A\pi^C - \pi^B\pi^D) \in \left]-\left(\frac{\Delta t_2}{\Delta t_1}\right)^2 \pi^D(\pi^C + \pi^D), \frac{\pi^B\pi^D}{\pi^A}\right[$ (see conditions RSC1, and RSC2 or RSC5).

The optimal strategy of the monopolist is defined as a set of price-quantity allocations satisfying IRC and ICC. With fixed quantities as defined previously, optimal prices are determined by the following equation:

$p^i = \frac{\partial u}{\partial q}(t^i, q^i) = \frac{\partial C}{\partial q}(q^i) - \sum_j \frac{\mu_{ji}}{\pi^i}(\frac{\partial u}{\partial q}(t^j, q^i) - \frac{\partial u}{\partial q}(t^i, q^i)).$

We can notice that the unit prices paid by buyers of type i are a convex combination of the marginal cost and of the marginal utilities of buyers that are attracted to i (his quantity vector q^i). In our case, with linear preferences, we get:

$p^i = \frac{\partial C}{\partial q}(q^i) - \sum_j \frac{\mu_{ji}}{\pi^i}(t^j - t^i).$

When i attracts no one ($\mu_{ji} = 0$ for all i, j), i pays prices equal to the marginal costs and gets his first best allocation. In the other case, ($\mu_{ji} < 0$) prices are always superior to marginal costs, because only downwards local ICC bind: as a consequence, in the R.S.C, $\mu_{ji} < 0$ implies that t^j is superior to t^i .

Proposition 1 *In the regular symmetric case, prices are superior to marginal costs except for the highest type who is charged with a price equal to marginal cost and gets his first best allocation in quantity. The price charged on a good depends on the consumed quantity of the other good: p_α^i depends on q_β^i. The optimal nonlinear pricing requires a kind of form of bundling.*

To show the second part of the proposition, we consider types A and D for the good 1: we know that $t_1^A = t_1^D$ and the solution gives the following result: $p_1^A > p_1^D$ and $q_1^A < q_1^D$ and this comes from the fact that $q_2^A < q_2^D$ as $t_2^A < t_2^D$. Symmetrically we obtain the same result on good 2 for types A and B.

When $\rho = 0$, we have the following solution for prices in the R.S.C:

$$t_\alpha^i = t_\alpha^h \iff p_\alpha^i = \frac{\partial C}{\partial q}(q_\alpha^i) \iff q_\alpha^i = \hat{q},$$
$$t_\alpha^i = t_\alpha^l \iff p_\alpha^i > \frac{\partial C}{\partial q}(q_\alpha^i) \iff q_\alpha^i < \hat{q},$$
$$\Rightarrow \text{no upward distortion.}$$

As in Lewis-Sappington (88), prices always exceed marginal costs, except for the highest type where they are equal.

4.2 Complete solution: the case of a general discrete distribution and $\rho = 0$

4.2.1 The Regular Symmetric Case

We have previously seen that the regular symmetric case does not exist for all distributions. This solution is defined by its two frontiers: $\mu_{CB} \leq 0$, and $q_1^D \geq q_1^A$ (or $q_2^B \geq q_2^A$, see figures 1 and 2). These two frontiers give the following conditions:

$$\mu_{CB} \leq 0 \iff \pi^A \pi^C - \pi^B \pi^D \geq -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D),$$

$$q_1^D \geq q_1^A \iff \pi^A \pi^C - \pi^B \pi^D \leq \frac{\pi^B \pi^D}{\pi^A}.$$

Proposition 2 *If $\pi^A \pi^C - \pi^B \pi^D \in [-(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D), \frac{\pi^B \pi^D}{\pi^A}]$ the solution is regular symmetric. Types C get their first best allocation and $q_1^D, q_1^A, q_2^B, q_2^A$ are downwards distorted. There is no upward distortion.*

4.2.2 The Separable Case

Now we assume that one of these two conditions is no longer satisfied anymore: if $\pi^A \pi^C - \pi^B \pi^D \geq \frac{\pi^B \pi^D}{\pi^A}$ this means that C is also directly attracted by A. Thus, the non local downward ICC is binding. As a consequence, $q_1^D = q_1^A$, $q_2^B = q_2^A$ and the solution is now separable (see diagram 2). $q_1^C, q_1^B, q_2^C, q_2^D$ are equal to the first best allocation.

Diagram 2 enables to compute the indirect utility levels and we get:

$$U^A = 0,$$
$$U^B = \Delta t_1 q_1^A,$$
$$U^D = \Delta t_2 q_2^A,$$
$$U^C = \Delta t_1 q_1^A + \Delta t_2 q_2^B = \Delta t_1 q_1^D + \Delta t_2 q_2^A = \Delta t_1 q_1^A + \Delta t_2 q_2^A.$$

The F.O.C and the conditions on quantities give:

$$\mu_{BA} + \mu_{DA} = \pi^A - 1, (\lambda^A = -1),$$
$$-\mu_{BA} + \mu_{CB} = \pi^B,$$
$$-\mu_{CA} - \mu_{CB} - \mu_{CD} = \pi^C,$$
$$\mu_{CD} - \mu_{DA} = \pi^D,$$
$$q_1^D = q_1^A,$$
$$q_2^B = q_2^A.$$

We get the following results:

$$\mu_{BA} = -\frac{\pi^B}{\pi^A + \pi^D}, \mu_{DA} = -\frac{\pi^D}{\pi^A + \pi^D},$$
$$\mu_{CB} = \pi^B + \mu_{BA} < 0, \mu_{CD} = \pi^D + \mu_{DA} < 0,$$
$$\mu_{CA} = \pi^B + \pi^C + \pi^D + \mu_{BA} + \mu_{DA} < 0.$$

Proposition 3 *When there is a strong positive correlation between types ($\pi^A \pi^C - \pi^B \pi^D \geq \frac{\pi^B \pi^D}{\pi^A}$), the non local downward ICC is binding, and the solution is separable: $q_1^D = q_1^A, q_2^B = q_2^A$, $q_1^C = q_1^B, q_2^C = q_2^D$. C gets his first best allocation and $q_1^D, q_1^A, q_2^B, q_2^A$ are downwards distorted.*

The optimal quantities are:

$$q_1^D = q_1^A = t_1^l - \frac{\pi^A + \pi^D}{\pi^B + \pi^C} \Delta t_1,$$
$$q_1^B = q_1^C = t_1^h,$$
$$q_2^B = q_2^A = t_2^l - \frac{\pi^A + \pi^B}{\pi^C + \pi^D} \Delta t_2,$$
$$q_2^D = q_2^C = t_2^h.$$

We have to check that all the Lagrange multipliers are negative under the condition

$$\pi^A \pi^C - \pi^B \pi^D \geq \frac{\pi^B \pi^D}{\pi^A}$$

and it is indeed the case. Conditions on quantities to satisfy the ICC are always true in this case.

For such a distribution, the optimal solution does not generate perfect screening and the allocations do not require the kind of form of bundling mentioned previously: for each type, the unit price charged on a good does not depend on the consumed quantity of the other good. Optimal quantities depend on the marginal distribution of types. But we still have the usual unidimensional result: prices are greater than marginal costs, except at the top of the distribution where they are equal.

4.2.3 The Regular Asymmetric Case

Now we assume that the other condition for R.S.C to be solution($\pi^A \pi^C - \pi^B \pi^D \geq -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D)$) , i.e., $\mu_{CB} < 0$) is no longer satisfied. In this case, we obtain a solution in which C is not attracted to B ($\mu_{CB} = 0$). We call it the regular asymmetric case (Regular because only downward or leftward ICC can be binding and Asymmetric because there is no attraction between B and C, whereas D attracts C)(see diagram 3) .

Diagram 3 enables to compute the indirect utility levels and we get:

$$U^A = 0,$$
$$U^B = \Delta t_1 q_1^A,$$
$$U^D = \Delta t_2 q_2^A,$$
$$U^C = \Delta t_1 q_1^D + \Delta t_2 q_2^A.$$

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The F.O.C give:

$$\mu_{BA} = -\pi^B,$$
$$-\mu_{DA} + \mu_{CD} = \pi^D,$$
$$\mu_{CD} = -\pi^C.$$

We get the following results:

$$\mu_{BA} = -\pi^B$$
$$\mu_{DA} = -\pi^D - \pi^C$$
$$\mu_{CD} = -\pi^C$$

Now we have to check that B is not attracted by C. This is equivalent to:

$$\Delta t_1 (q_1^D - q_1^A) \leq \Delta t_2 (q_2^C - q_2^A),$$

and this condition implies after computations that:

$$\pi^A \pi^C - \pi^B \pi^D \geq -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^A + \pi^C + \pi^D).$$

The same condition applies to show that B is not attracted to D.

Proposition 4 *When $\pi^A \pi^C - \pi^B \pi^D \in [-(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^A + \pi^C + \pi^D), -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D)]$ the solution is regular asymmetric: B and C receive their first best allocation, whereas q_1^D, q_1^A, q_2^A are distorted downwards.*

The optimal quantities are:

$$q_1^A = t_1^l - \frac{\pi^B}{\pi^A} \Delta t_1,$$

$$q_2^A = t_2^l - \frac{\pi^C + \pi^D}{\pi^A} \Delta t_2,$$

$$q_1^D = t_1^l - \frac{\pi^C}{\pi^D} \Delta t_1,$$

$$q_2^D = t_2^h,$$
$$q_1^B = t_1^l,$$
$$q_2^B = t_2^h,$$
$$q_1^C = t_1^h,$$
$$q_2^C = t_2^h.$$

Note that D is not attracted to B if:

$$\pi^A \pi^C - \pi^B \pi^D \geq -(\frac{\Delta t_1}{\Delta t_2})^2 \pi^B (\pi^A + \pi^C + \pi^D).$$

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If we had not assumed that $\Delta t_1 \pi^B > \Delta t_2 \pi^D$, we would have obtained the same condition for B and D to not attract each other.

In this case the unidimensional qualitative properties are almost satisfied. For the good 1, the usual results are satisfied in the sense that the downward local ICC are binding (C is attracted to D, and B is attracted to A). This is not the case on the market of good 2: D is attracted to A, but C is not attracted to B. We also have to notice that two different types get their first best allocation(these types pay prices equal to marginal costs) and perfect screening is obtained in this optimal solution.

Under this condition, $\pi^A \pi^C - \pi^B \pi^D \geq -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D)$, the Lagrange multipliers are all non positive, and conditions on quantities are all satisfied.

4.2.4 The Singular Case

Now we assume that $\pi^A \pi^C - \pi^B \pi^D \leq -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^A + \pi^C + \pi^D)$, i.e., $(\Delta t_1 (q_1^D - q_1^A) \leq \Delta t_2 (q_2^C - q_2^A))$ is not satisfied anymore), and B is now attracted to C and D.This condition also means that

$$\pi^B \geq \frac{\Delta t_1}{\Delta t_1 + \Delta t_2} \frac{\pi^A \pi^C}{\pi^D} + \frac{\Delta t_2}{\Delta t_1 + \Delta t_2}.$$

In this case the solution is singular: surprisingly, the transverse and an upward ICC are binding (see diagram 4).

Diagram 4 enables to compute the indirect utility levels and we get:

$$U^A = 0,$$
$$U^B = \Delta t_1 q_1^A = \Delta t_1 q_1^D - \Delta t_1 q_2^D + U^D,$$
$$U^D = \Delta t_2 q_2^A,$$
$$U^C = \Delta t_1 q_1^A + \Delta t_2 q_2^C = \Delta t_1 q_1^D + \Delta t_2 q_2^A.$$

The F.O.C and the conditions on quantities give:

$$\mu_{BD} + \mu_{CD} - \mu_{DA} = \pi^D,$$
$$-\mu_{BA} - \mu_{BC} - \mu_{BD} = \pi^B,$$
$$\mu_{BC} - \mu_{CD} = \pi^C,$$
$$q_2^C = q_2^D,$$
$$\Delta t_1 (q_1^D - q_1^A) = \Delta t_2 (q_2^D - q_2^A).$$

We get the following results:

We check the sign of μ_{ij}s:

$$\frac{\mu_{BC}}{\pi^C} = \frac{\mu_{BD}}{\pi^D} \rightarrow \mu_{BC} = -\theta \pi^C \text{ and } \mu_{BD} = -\theta \pi^D,$$

$$\mu_{CD} = -(1 + \theta)\pi^C \text{ and } \mu_{DA} = -(1 + \theta)(\pi^C + \pi^D),$$

$$\text{and } \mu_{BA} = -\pi^B + \theta(\pi^C + \pi^D).$$

$$(\Delta t_1)^2 [-\frac{\mu_{CD} + \mu_{BD}}{\pi^D} + \frac{\mu_{BA}}{\pi^A}] = (\Delta t_2)^2 [\frac{\mu_{BD}}{\pi^D} + \frac{\mu_{DA}}{\pi^A}] \text{ gives the following for } \theta,$$

$$\theta = \frac{(\pi^B \pi^D - \pi^A \pi^C)\Delta t_1^2 - \Delta t_2^2 \pi^D (1 - \pi^B)}{\Delta t_1^2 (\pi^C + \pi^D)(\pi^A + \pi^D) + \Delta t_2^2 \pi^D (1 - \pi^B)} \leq 0 \text{ by assumption.}$$

Proposition 5 *When $\pi^A \pi^C - \pi^B \pi^D \leq -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^A + \pi^C + \pi^D)$ the solution is singular. B gets his first best allocation and C attracts B. As a consequence q_2^C is distorted upwards. D also attracts B and consequently q_{12}^D is distorted upwards.*

All the conditions on the quantities are always satisfied for such distributions.

In this solution, it is optimal, for the monopolist, to price below the marginal cost on good 2 for types C and D and to give the first best allocation to an "intermediary" type, type B.

The intuition for upward distortions is as follows: proportion of type B is so high that it is in the seller's interest to extract maximum surplus from them and thus sell them their first best allocation. But the seller has also to prevent types B from choosing the allocations offered to other types, in particular type C. In order to reduce competition between q^C and q^D, it is therefore optimal to increase q_2^C above the first best level.

To sum up, here are the four solutions of the monopolist's problem:

- $\pi^A \pi^C - \pi^B \pi^D \in [\frac{-1}{4}, -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^A + \pi^C + \pi^D)]$: Singular Solution.

- $\pi^A \pi^C - \pi^B \pi^D \in [-(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^A + \pi^C + \pi^D), -(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D)]$: Regular Asymmetric Solution.

- $\pi^A \pi^C - \pi^B \pi^D \in [-(\frac{\Delta t_2}{\Delta t_1})^2 \pi^D (\pi^C + \pi^D), \frac{\pi^B \pi^D}{\pi^A}]$: Regular Symmetric Solution.

- $\pi^A \pi^C - \pi^B \pi^D \in [\frac{\pi^B \pi^D}{\pi^A}, \frac{1}{4}]$:Separable Solution.

We have seen that, in our problem, four possible solutions exist depending on the correlation of types. Dana (1993) also finds solutions depending on the correlation of types but only gets two since he assumes that $\Delta t_1 = \Delta t_2$ and $\pi^B = \pi^D$.

4.3 Complete Solution: the case of a Uniform Discrete Distribution and $\rho \in]-1, 1[$

We assume:

$$\pi^A = \pi^C = \frac{\epsilon}{2},$$
$$\pi^B = \pi^D = \frac{(1-\epsilon)}{2}.$$

See Appendix 2 and figure 4.

We have obtained four solutions in the previous section: we call respectively A,C,D,E the singular case, the regular asymmetric case, the regular symmetric case and the separable case. We obtain ten other solutions (see diagrams) depicted in figure 4. Two constraints are always binding: for all (ϵ, ρ) the individual rationality constraint of types A (not surprising) and $IC(AD)$ that is D is always attracted to A. Two other constraints never bind: $IC(CA)$ and $IC(CD)$.

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There are two solutions (G and N) where the seller never offers a first best allocation. Whatever the type is, the allocation is distorted.

We go from D to C when μ_{CB} becomes positive, then $IC(BC)$ is not binding anymore.

We go from C to A when $IC(CB), IC(DB)$ fail, then they are binding.

We go from A to B when μ_{BD} becomes positive.

We go from D to E when $IC(AC)$ fails.

We go from E to F when μ_{CB} becomes positive.

We go from F to G when $IC(CB), IC(BC)$ fail.

We go from G to H when μ_{CB} becomes positive.

We go from H to M when μ_{BA} becomes positive.

We go from M to N when $IC(BC)$ fails.

We go from D to K when $IC(DB)$ fails.

We go from K to J when μ_{CD} becomes positive.

We go from J to I when μ_{BA} becomes positive.

4.3.1 Case B

An upward ICC is binding (B is attracted to C). As a consequence, q^C is distorted upwards for the same reasons than in case A. B gets his first best allocation.

4.3.2 Case F

B and C get their first best allocation. q_2^D is not distorted, whereas q_1^A, q_1^D, q_2^A are distorted downwards. The solution is separable on the market of good 1 (the solution is separable on the market of good α means: $t_\alpha^i = t_\alpha^j \rightarrow q_\alpha^i = q_\alpha^j$): $q_1^A = q_1^D < q_1^B = q_1^C$.

4.3.3 Case G

This solution is similar to the case E solution, but B is attracted to C. This means that $q_2^A = q_2^B = q_2^C$ whereas q_2^D is optimal. The solution is not globally separable anymore, but it is still separable on the market of good 1. In this case, the seller never offers a first best allocation.

4.3.4 Case H

B does not attract C, but is attracted to C. As a consequence q_2^C is distorted upwards and the solution is separable for the good 1. B gets his first best allocation even if π^B becomes relatively small (when ϵ increases).

4.3.5 Case I

The downward local ICC are only binding on the market of good 2: C is attracted to B and D is attracted to A. The transverse ICC is also binding (B is attracted to D). As a consequence we obtain this condition on the quantities obtained by types B and D :

$$\Delta t_1(q_1^B - q_1^D) > \Delta t_2(q_2^D - q_2^B).$$

C gets his first best allocation.

4.3.6 Case J

C gets his first best allocation and we obtain the following conditions on quantities:

$$\Delta t_1(q_1^B - q_1^A) = \Delta t_2(q_2^D - q_2^A),$$
$$\Delta t_1(q_1^D - q_1^A) > \Delta t_2(q_2^B - q_2^A).$$

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4.3.7 Case K

This solution is similar to the regular symmetric case but the transverse ICC is binding. This solution differs from the case D solution because we obtain:

$$q_1^A \leq q_1^D \leq q_1^B \leq q_1^C,$$
$$q_2^A \leq q_2^D = q_2^B \leq q_2^C.$$

B and D receive the same quantity of good 2.

4.3.8 Case L

The solution differs from the case K one because $q_2^D > q_2^B$ and B gets his first best allocation. As in case C, the proportion of type B is so high that it is in the seller's interest to offer them their first best allocation to extract the maximum surplus from them.

4.3.9 Case M

B gets his first best allocation whereas C receives an upwards distorted allocation. It is surprising in this case, as in the case H (especially the South-East of the H area), because the proportion of buyers of type B is relatively small. The solution is separable for the good 1.

4.3.10 Case N

The seller does not offer any first best allocation. The solution is separable for the good 1. For the market of good 2, D receives his first best allocation and

$$q_2^D = q_2^B.$$

5 The Equivalent Approach

In our simple model (discrete distribution of four types of buyers, linear utilities in money), we defined the global solution to the monopolist's problem: we defined the allocations and rents for each solution. To do so, following Spence (80)we maximize the expected profit of the seller under Individual Rationality Constraints (IRC) and Incentive Compatibility Constraints (ICC); we decompose the problem into two subproblems:

- minimize the agents's expected utilities for fixed allocations

- Choose the allocation so as to maximize the expected surplus minus the expected utilities

Rents are defined so that IRC and ICC are satisfied and computed according to the binding constraints (or attractions, see Border-Sobel (87)).

These attractions allow us to define optimal paths from a type of agent to a dummy type (the "lowest type", type A in chapter 2) that enable to compute these rents. Thanks to Rochet (87) that shows that closed paths (from a type of agents to himself) do not increase expected utility (and are thus non optimal), we know that the rents defined by optimal paths from a type to the dummy type are optimal.

Once we know the solution and the optimal rents we can write the monopolist's problem as:

- Compute the optimal rents according to binding constraints.

- maximize the expected profit of the seller under the constraints that each type of agents gets his optimal rent.

This new formulation of the seller's problem, the equivalent problem hereafter, which of course leads to the same solution, enables to explain distortions in resource allocation. Distortions depend on optimal paths and more especially of the length (the number of type involved in the path) and the number of these optimal paths that define a solution.

After some brief remarks on the above results, we study the equivalent problem and explain the way allocations are distorted. We confirm Rochet-Chone (1998) that defines the sets of agents who do participate as: i) a set of types who get no rent: this set is in fact reduced to a singleton, ii) a set of types who get strictly positive rents and iii) a set of types who get strictly positive rents and their first best allocations. We then study the Regular Symmetric Case (see case D in section 4) to show the equivalence of the two problems and to explain distortions in resource allocations. We also study the general solution (defined in section 4) and define several sets of solutions: ordered types, called **Pure Cases** (solutions that enables to define a complete type ordering implying uniqueness of rents), single optimum, called **Almost Pure Cases**(uniqueness of rents and partial type ordering), several optima, regular solutions (only downward binding ICC), singular solutions (some upward or transverse ICC are binding). We also exhibit two special cases in which the monopolist only produces one good and this is closed, but not equivalent, to Armstrong (96) who shows that it is sometimes optimal for the monopolist to exclude some customers from its products in order to extract more revenue from other higher value consumers.

5.1 Remarks

As defined in Border-Sobel (87), we say that j attracts i when $IC(i,j)$ is binding. These attractions (who attracts whom?) are crucial for determining distortions in resource allocation and also to compute rents. If j attracts i we can define U^i as a function of U^j and q^j. If j is attracted by another type, say k, we can define his rent as a function of U^k and q^k and so on. If j is not attracted by any other type, this means that j is the dummy type or lowest type and his IRC is binding (see section 4).

A path is defined as a way to reach the dummy type from another type (with one or several steps from type to type). An optimal path from one type to another is defined as a succession of attractions from one type to the dummy. As successions of attractions always lead to the dummy type (see section 4), we can compute the set of rents using backward induction. This means that the set of possible paths defines the set of possible rents and the set of optimal paths defines a solution and the optimal rents associated to this solution.

Example: i is attracted to j and j is attracted to the dummy type, say k. This defines the optimal paths $\gamma^i = \{i \rightarrow j \rightarrow k\}, \gamma^j = \{j \rightarrow k\}$. Then, we have:

$$U^i = U^j + u(t^i, q^j) - u(t^j, q^j)$$
$$U^j = U^k + u(t^j, q^k) - u(t^k, q^k)$$
$$U^k = 0$$

then, we obtain:

$$U^i = u(t^i, q^j) - u(t^j, q^j) + u(t^j, q^k) - u(t^k, q^k)$$
$$U^j = u(t^j, q^k) - u(t^k, q^k)$$
$$U^k = 0.$$

This enables to solve the first subproblem of the monopolist's problem: "minimize expected utilities". We can then define a set of rents $U(q)$ such that ICC are satisfied for all i, j and the rent of the lowest type is zero. According to these attractions, we can say that j is an immediate successor of i and also an immediate predecessor of j. This also means that for any optimal path we are able to define an ordered type subset where $\{i \rightarrow j \rightarrow k\}$ is equivalent to:

$$i \succeq j \succeq k.$$

Consequently, for any solution, we can reorganize T into a partition of ordered subsets Υ.

We define as closed paths, successions of attractions that leads one type to himself. Using Lemmas from Rochet (87): *considering arbitrary paths in the set of types T, a path from type t^i to t^j is denoted by a function γ. We denote the "length" of $\gamma : \{0, 1, ...l\} \rightarrow T$. Finally, we say that a path of length l is closed if: $\gamma(0) = \gamma(l)$.*

Lemma 1: $U(q)$ is non-empty if and only if for every closed path γ :

$$\sum_{k=0}^{l-1} u(t_{\gamma(k+1)}, q_{\gamma(k)}) - u(t_{\gamma(k)}, q_{\gamma(k)}) \leq 0. \quad \cdot$$

Lemma 2: When the above condition is satisfied, $U(q)$ has a unique element $U\_$, characterized for all i by:

$$U^i\_ = \sup_{\gamma} \sum_{k=0}^{l-1} u(t_{\gamma(k+1)}, q_{\gamma(k)}) - u(t_{\gamma(k)}, q_{\gamma(k)})$$

where the sup is taken over all the possible open paths from type t^i to the dummy type, whose utility is zero.

This means that rents computed according to optimal paths from a type to the dummy one are optimal. On the one hand, these rents do not depend on the distribution of types but only on the set of types. On the other hand, quantities and distortions, on which depends these rents, depend on the distribution of types (see section 4).

5.2 The Monopolist's Equivalent Problem

As we know how to compute the optimal rents according to optimal paths, we can now write the monopolist's problem as:

$$Max \sum_i \pi^i(u(t^i, q^i) - C(q^i) - U\_^i)$$

$$s/c : U\_^i = \sup_{\gamma^i} \sum_{k=0}^{l-1} u(t_{\gamma^i(k+1)}, q_{\gamma^i(k)}) - u(t_{\gamma^i(k)}, q_{\gamma^i(k)}) \text{ for all } i.$$

From section 4, we know that whatever the solution:

$$U\_{}^A = 0.$$

We can explain this as follows: at least for one type, A in our model, the IRC is binding. Since adding a uniform fee in the price schedule does alter the ICC and increases the seller's profit, it's optimal for the monopolist to give no rent to the dummy type.

We also know that there are usually several ways to compute the optimal rents of the other types. There exists as many ways to compute these rents as the number of possible optimal paths from one type to the dummy type.

For example, if there exists two possible optimal paths from type t^C to t^A, γ_1^C through B and γ_2^C through D, there are clearly two expressions for $U\_{}^C$. In this particular example, the Regular Symmetric Case, we have:

$$\gamma^C = \{\gamma_1^C, \gamma_2^C\}$$

$$U^C(\gamma_1^C) = \Delta t_2 q_2^B + \Delta t_1 q_1^A,$$
$$U^C(\gamma_2^C) = \Delta t_1 q_1^D + \Delta t_2 q_2^A.$$

This means that in this particular case, there are two constraints on type t^C : the constraint

$$U\_{}^C = \max_{\gamma^C} U^C(\gamma^C) \text{ for all } \gamma^C$$

is equivalent to:

$$U\_{}^C = U^C(\gamma_1^C),$$
$$U\_{}^C = U^C(\gamma_2^C),$$

or

$$U\_{}^C = \sigma_1^C U^C(\gamma_1^C) + \sigma_2^C U^C(\gamma_2^C),$$
$$\sigma_1^C + \sigma_2^C = 1,$$

considering σ_j^C like "the probability that type t^C chooses path γ_j^C to reach the dummy type".

Once we know the solutions, we are able to identify, for all types, all the possible expressions of the optimal rents in each solution. To solve the monopolist's problem, we have to define for all solutions, the set of possible optimal paths: for solution $s \in s^*$, we define $\gamma(s)$ as the set of possible paths. In $\gamma(s)$, we define for all t^i all the possible paths to reach t^A as $\gamma^i(s)$:

$\gamma^i(s) = \{\gamma_1^i, \gamma_2^i ... \gamma_n^i\}$ if there are n possible optimal paths from t^i to t^A.

$\gamma(s) = \{\gamma_p^i,$ for all i, for all possible optimal paths $p\}$.

Notice that if type $t^j \neq t^i$ belongs to one of the optimal paths γ_p^i from t^i to t^A, this means that the truncation of γ_p^i between t^j and t^A defines an optimal path between these two types and also an expression of the optimal rent of type t^j. From the above example, this means that an expression of $U\_{}^B$ is:

$$U\_{}^B = \Delta t_1 q_1^A,$$

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since B belongs to γ_1^C and an expression of $U\_^D$ is:

$$U\_^D = \Delta t_2 q_2^A,$$

since D belongs to γ_2^C.

To refer to the above formulation of the monopolist's problem, we define a type ordering for each optimal path. γ_1^C defines the following type ordering:

$$C \succsim B \succsim A$$

this means that in this optimal paths B is the immediate successor of C and A is the immediate successor of B and this defines the unique γ^B; γ_2^C defines the following type ordering:

$$C \succsim D \succsim A$$

this means that in this optimal paths D is the immediate successor of C and A is the immediate successor of D and this defines the unique γ^D. We can reorganize T into a partition of ordered subsets Υ :

$$\Upsilon_1 = \{C, B, A\},$$
$$\Upsilon_2 = \{C, D, A\}.$$

As γ_1^C is of length 2 ($l = 2$), we can define:

$$U^C(\gamma_1^C) = \sum_{k=0}^{l-1} u(t_{\gamma_1^c(k+1)}, q_{\gamma_1^c(k)}) - u(t_{\gamma_1^c(k)}, q_{\gamma_1^c(k)(k)})$$

where $k = 2$ represents the highest type, C in this example, $k = 1$ represents the immediate successor to the highest type in the optimal path γ_1^C, B and $k = 0$ represents the dummy type, A. We also define:

$$U^C(\gamma_2^C) = \sum_{k=0}^{l-1} u(t_{\gamma_2^c(k+1)}, q_{\gamma_2^c(k)}) - u(t_{\gamma_2^c(k)}, q_{\gamma_2^c(k)(k)})$$

where $k = 2$ represents the highest type, C in this example, $k = 1$ represents the immediate successor to the highest type in the optimal path γ_1^C, D and $k = 0$ represents the dummy type, A.

The Lagrangian of the problem can now be written as:

$$L(U, q) = \sum_i \{\pi^i(u(t^i, q^i) - C(q^i) - U\_^i) - \sum_j \lambda_j^i(U\_^i - U^i(\gamma_j^i))\}$$

$$= \sum_i \{\pi^i(u(t^i, q^i) - C(q^i) - U\_^i)$$

$$- \sum_j \lambda_j^i[U\_^i - (\sum_{k=0}^{l-1} u(t_{\gamma_j^i(k+1)}, q_{\gamma_j^i(k)}) - u(t_{\gamma_2^i(k)}, q_{\gamma_j^i(k)(k)}))]\}.$$

where λ_j^i represents the non positive multipliers associated to the constraints on the optimal rent of type t^i computed along the optimal path γ_j^i.

The first order conditions (which are necessary and sufficient for this linear program) give:

$$\frac{\partial L}{\partial U^i} = -\pi^i - \sum_j \lambda^i_j = 0, \text{ for all } i,$$

$$\Longleftrightarrow \pi^i = -\sum_j \lambda^i_j, \text{ for all } i,$$

and:

$$\frac{\partial L}{\partial q^i} = \pi^i \frac{\partial S(t^i, q^i)}{\partial q^i} + \sum_{k \neq i} \sum_j \lambda^k_j \frac{\partial U^k(\gamma^k_j)}{\partial q^i} = 0, \text{ for all } i,$$

$$\Longleftrightarrow \frac{\partial S(t^i, q^i)}{\partial q^i} = -\frac{1}{\pi^i} \sum_{k \neq i} \sum_j \lambda^k_j \frac{\partial U^k(\gamma^k_j)}{\partial q^i} = \text{ for all } i.$$

We make the sum for all $k \neq i$ as closed paths are not optimal. This means that there exists no (classical) solution when two types attract each other (see special cases in section 6, in which the monopolist only produces good 1). We also have:

$$\frac{\partial U^k(\gamma^k_j)}{\partial q^i} = (t^{i+1} - t^i), \text{ for all } i.$$

We can also write the Lagrangian of the problem as:

$$L(U, q) = \sum_i \{\pi^i(u(t^i, q^i) - C(q^i) - U\_^i) - \lambda^i \sum_j \sigma^i_j(U\_^i - U^i(\gamma^i_j))\}$$

$$= \sum_i \{\pi^i(u(t^i, q^i) - C(q^i) - U\_^i)$$

$$- \lambda^i \sum_j \sigma^i_j [U\_^i - (\sum_{k=0}^{l-1} u(t_{\gamma^i_j(k+1)}, q_{\gamma^i_j(k)}) - u(t_{\gamma^i_2(k)}, q_{\gamma^i_j(k)}(k)))]\},$$

where λ^i is the Lagrange multiplier of the constraint: the optimal rent of type t^i is a combination of all the possible rents $U^i(\gamma^i_j)$ which can be chosen by types t^i who reach t^A along the optimal path γ^i_j with probability σ^i_j:

$$U\_^i = \sum_j \sigma^i_j(U\_^i - U^i(\gamma^i_j)), \text{ for all } i \text{ and } j,$$

$$\sum_j \sigma^i_j = 1.$$

In this case we obtain as first order conditions:

$$\frac{\partial L}{\partial U^i} = -\pi^i - \lambda^i \sum_j \sigma^i_j = 0, \text{ for all } i,$$

$$\Longleftrightarrow \pi^i = -\lambda^i \text{for all } i,$$

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and:

$$\frac{\partial L}{\partial q^i} = \pi^i \frac{\partial S(t^i, q^i)}{\partial q^i} + \sum_{k \neq i} \sum_j \pi^k \sigma_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q^i} = 0, \text{ for all } i,$$

$$\iff \frac{\partial S(t^i, q^i)}{\partial q^i} = -\frac{1}{\pi^i} \sum_{k \neq i} \sum_j \pi^k \sigma_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q^i} = \text{ for all } i.$$

5.3 Optimal Resource Allocations

The first order conditions with respect to q^i give:

$$\frac{\partial S(t^i, q^i)}{\partial q^i} = -\frac{1}{\pi^i} \sum_{k \neq i} \sum_j \lambda_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q^i}, \text{ for all } i,$$

where i belongs to one of the optimal paths that links types t^k to the dummy type. If types t^i do not belong to any optimal paths, this means that it does not attract any types. In this case,

$$\sum_{k \neq i} \sum_j \lambda_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q^i} = 0$$

and the first order condition gives:

$$\frac{\partial S(t^i, q^i)}{\partial q^i} = 0$$

and types t^i obtain their first best allocation.

In our setting, when $\rho = 0$, the first order conditions can be written as:

$$\frac{\partial L}{\partial q_\alpha^i} = \pi^i \frac{\partial S(t^i, q^i)}{\partial q_\alpha^i} + \sum_{k \neq i} \sum_j \lambda_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q_\alpha^i} = 0, \text{ for all } i \text{ and } \alpha = 1, 2,$$

$$\iff \pi^i (t_\alpha^i - q_\alpha^i) + \sum_{k \neq i} \sum_j \lambda_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q_\alpha^i} = 0, \text{ for all } i \text{ and } \alpha = 1, 2,$$

$$\iff \pi^i (t_\alpha^i - q_\alpha^i) + \sum_{k \neq i} \sum_j \lambda_j^k (t_\alpha^{i+1} - t_\alpha^i) = 0, \text{ for all } i \text{ and } \alpha = 1, 2,$$

$$\iff q_\alpha^i = t_\alpha^i + \frac{1}{\pi^i} \sum_{k \neq i} \sum_j \lambda_j^k (t_\alpha^{i+1} - t_\alpha^i), \text{ for all } i \text{ and } \alpha = 1, 2,$$

$$\iff q_\alpha^i = t_\alpha^i + \frac{1}{\pi^i} \sum_{k \neq i} \sum_j \pi^k \sigma_j^k (t_\alpha^{i+1} - t_\alpha^i), \text{ for all } i \text{ and } \alpha = 1, 2$$

The surplus function is assumed to be convex, differentiable in q and has, for all t, a unique maximum $\hat{q}(t)$. The set of $\hat{q}(t)$ will be used as a benchmark for evaluating the distortions in resource allocations entailed by the monopoly power under bidimensional adverse selection; the first best allocation is:

$$\hat{q}(t_\alpha^i) = t_\alpha^i, \text{ for all } i \text{ and } \alpha = 1, 2,$$

and distortions:

$$q(t_\alpha^i) - \hat{q}(t_\alpha^i) = \frac{1}{\pi^i} \sum_{k \neq i} \sum_j \lambda_j^k (t_\alpha^{i+1} - t_\alpha^i), \text{for all } i \text{ and } \alpha = 1, 2,$$

$$\Longleftrightarrow q(t_\alpha^i) - \hat{q}(t_\alpha^i) = \frac{\lambda(q, t^i)}{\pi^i}(t_\alpha^{i+1} - t_\alpha^i), \text{for all } i \text{ and } \alpha = 1, 2$$

where:

$$\lambda(q, t^i) = \sum_{k \neq i} \sum_j \lambda_j^k \leq 0,$$

$$\lambda(q, t^i) = -\sum_{k \neq i} \sum_j \pi^k \sigma_j^k \leq 0$$

which depends on q (see section 4).

The distortion in $q(t_\alpha^i)$ can be seen as a ratio between the weighted sum of the differences between t^i's predecessor and t^i and the proportion of types t^i in the population. The weights are represented by λ_j^k, Langrange multiplier associated to the constraint:

$$U\_^k - U^k(\gamma_j^k) = 0.$$

Even if $\lambda(q, t^i)$ is always negative, the sign of the distortion depends on the sign of $[t^{i+1} - t^i]$: upwards distortion if it is positive, downwards otherwise. The sign of the distortion of type t^i's allocation only depends on its predecessor's type. If type $\bar{t}$ is attracted to type t^i (t^i is $\bar{t}$'s immediate successor) and if there exists a good α such $\bar{t}_\alpha - t_\alpha^i < 0$, then:

$$q(\bar{t}_\alpha) = \hat{q}(\bar{t}_\alpha),$$
$$q(t_\alpha^i) > \hat{q}(t_\alpha^i).$$

This generalizes the result of no distortion at the top of the distribution: the highest type $\bar{t}$ who attracts no other type, gets his first best allocation. The intuition for upward distortion: if the proportion of type $\bar{t}$ is high it might be interesting for the monopolist's to extract the maximum surplus from type t^i and thus sell them their first best allocation. In this case, the seller has also to prevent type $\bar{t}$ from choosing the other types's allocations and especially his immediate successor's allocation, $q(\bar{t}^{-1})$. To reduce competition between $q(\bar{t})$ and $q(\bar{t}^{-1})$ it might be therefore optimal for the seller to increase $q(\bar{t}_\alpha^{-1})$ above the first best level and this is the case when:

$$\bar{t}_\alpha^{-1} > \bar{t}_\alpha.$$

- We call **Pure Case** a solution such that there is for the highest type an optimal path which runs through all of the types (and also unique since no closed paths are optimal), this means that we can define a unique ordered subset $\Upsilon \in T$. We can then rank these types from t^0, the dummy type to $\bar{t}$, the highest type:

$$\Upsilon = \{t^0, t^1..., \bar{t}\}.$$

This also means that if there are T types, the longest optimal path, from $\bar{t}$ to t^0 is of length $T-1$. And for all optimal path of length l we have:

$$\gamma(l-1) \subset \gamma(l), \text{ for all } l = \{1, ..., T-1\}.$$

In this particular case, the first order conditions give:

$$\frac{\partial L}{\partial U^i} = -\pi^i - \lambda^i = 0, \text{ for all } i,$$

$$\Longleftrightarrow \lambda^i = -\pi^i, \text{ for all } i,$$

$$\Rightarrow q(t^i_\alpha) - \hat{q}(t^i_\alpha) = \frac{1}{\pi^i} \sum_{k>i} \pi^k (t^{i+1}_\alpha - t^i_\alpha), \text{ for all } i \text{ and } \alpha = 1, 2,$$

$$\Longleftrightarrow q(t^i_\alpha) - \hat{q}(t^i_\alpha) = \frac{1 - \sum_{k \leq i} \pi^k}{\pi^i} (t^{i+1}_\alpha - t^i_\alpha), \text{ for all } i \text{ and } \alpha = 1, 2.$$

In this particular case, as in the classic one-dimensional case, $\lambda(q, t^i)$ does not depend on q,

$$\lambda(q, t^i) = -\frac{1 - \sum_{k \leq i} \pi^k}{\pi^i}, \text{ for all } i.$$

As a consequence, the subproblem 2 can be solved by maximizing the virtual surplus $S_v(t^i, q^i)$:

$$S_v(t^i, q^i) = S(t^i, q^i) - \lambda(q, t^i)[u(t^{i+1}, q^i) - u(t^i, q^i)], \text{ for all } i,$$

$$S_v(t^i, q^i) = S(t^i, q^i) - \frac{1 - \sum_{k \leq i} \pi^k}{\pi^i} [t^{i+1} - t^i] q^i, \text{ for all } i$$

$$S_v(\bar{t}, \bar{q}) = S(\bar{t}, \bar{q}).$$

where $\bar{t}$ is the highest type, nobody's successor. This generalizes the result of no distortion at the top of the distribution. But this does not imply that allocations are only downward distorted.

- We call **Almost Pure Case** a solution such that there is a single optimal path to compute the rent of each type, this does not mean, as above, that there exists a single optimal path running through all the types. This means that we can define several ordered subsets, say J:

$$\Upsilon = \{\Upsilon_1, \Upsilon_2 ... \Upsilon_J\},$$

and for every Υ_j we can rank its types from t^0_j, the dummy type in Υ_j to $\bar{t}_j$, the highest type in Υ_j. $t^0_j = t^0$ for all j. Υ is such that :

$$\Upsilon_1 \cap \Upsilon_2 \cap ... \cap \Upsilon_J = \{t^0\}.$$

This shows an important result (which is valid for all solutions, not only almost pure cases):

Proposition 6 *whatever the solution, the set of types that participate and get no rent is always a singleton, the dummy type, if all the quantities served by the monopolist are strictly positive.*

To show this, imagine there are two such types, t_j^0 the lowest type in Υ_j and t_i^0 the lowest type in Υ_j, as nobody attracts them, we have (which is also equivalent to say that attract each other, i.e, a closed path exists between t_j^0 and t_i^0):

$$U_j^{\prime 0} = U_i^{\prime 0}.$$

We also have:

$$
\begin{aligned}
U_j^0 - U_i^0 &= (t_j^0 - t_i^0)q_i^0 = 0, \\
U_i^0 - U_j^0 &= (t_i^0 - t_j^0)q_j^0 = 0, \\
&\Longrightarrow q_{j\alpha}^0 = q_{i\alpha}^0 = 0 \text{ for all } (t_{i\alpha}^0 - t_{j\alpha}^0) \neq 0.
\end{aligned}
$$

If $(t_{i\alpha}^0 - t_{j\alpha}^0) > 0$, this means that $q_{i\alpha}^0$ is upwards distorted and $q_{j\alpha}^0$ is downwards distorted, then we have:

$$q_{i\alpha}^0 > \hat{q}_{i\alpha}^0 > \hat{q}_{j\alpha}^0 > q_{j\alpha}^0,$$

which cannot be satisfied with:

$$q_{j\alpha}^0 = q_{i\alpha}^0.$$

As a consequence, $q_{j\alpha}^0 = q_{i\alpha}^0 = 0 (QED)$. Then we define by l_{ji} the length of the optimal path of type t^i in subset Υ_j , $\bar{l}_j$ the length of the longest one and by $\gamma(\bar{l}_j)$ this optimal path from $\bar{t}_j$ to t^0. This means that for all $i \neq 0$, there exists a unique $\gamma(\bar{l}_j)$ running through t^i. And for all optimal path of length l_j we have:

$$\gamma(l_j - 1) \subset \gamma(l_j), \text{ for all } l = \{1, ..., \bar{l}_j\},$$
$$\sum_j \bar{l}_j = T - 1.$$

In this case, the first order conditions give:

$$
\begin{aligned}
\frac{\partial L}{\partial U^i} &= -\pi^i - \lambda^i = 0, \text{ for all } i, \\
&\Longleftrightarrow \lambda^i = -\pi^i, \text{ for all } i, \\
&\Rightarrow q(t_\alpha^i) - \hat{q}(t_\alpha^i) = \frac{1}{\pi^i} \sum_{k>i} \pi^k (t_\alpha^{i+1} - t_\alpha^i),
\end{aligned}
$$

for all $i, i+1, k \in j$ and $\alpha = 1, 2,$

$$\Longleftrightarrow q(t_\alpha^i) - \hat{q}(t_\alpha^i) = \frac{1 - \sum_{k \leq i} \pi^k}{\pi^i} (t_\alpha^{i+1} - t_\alpha^i),$$

for all $i, i+1, k \in j$ and $\alpha = 1, 2.$

As above, $\lambda(q, t^i)$ does not depend on q

$$\lambda(q, t^i) = -(1 - \sum_{k \leq i} \pi^k), \text{ for all } i, i+1, k \in j.$$

As a consequence, the subproblem 2 can be solved by maximizing the virtual surplus:

$$S_v(t^i, q^i) = S(t^i, q^i) - \frac{1 - \sum_{k \leq i} \pi^k}{\pi^i} [u(t^{i+1}, q^i) - u(t^i, q^i)], \text{ for all } i \neq \bar{t}_j,$$
$$S_v(\bar{t}_j, \bar{q}_j) = S(\bar{t}_j, \bar{q}_j) \text{ for all } j.$$

- In a much more complex solution, in which some types can reach the dummy type with several optimal paths, we can also define several ordered subsets $\Upsilon_1, \Upsilon_2...\Upsilon_J$ but

$$\Upsilon_1 \cap \Upsilon_2 \cap ... \cap \Upsilon_J \neq \{t^0\},$$

the intersection of all these ordered subsets is not reduced to a singleton. In this case,

$$\lambda(q, t^i) = \sum_{k \neq i} \sum_j \lambda_j^k$$

depends on q. We can notice that:

$$\pi^i = -\sum_j \lambda_j^i, \text{ for all } i,$$

$$= -\pi^i \sum_j \sigma_j^i, \text{ for all } i,$$

and

$$\sum_j \sigma_j^i = 1, \text{ for all } i$$

which means that:$\lambda_j^i \in [-\pi^i, 0]$, for all i, j. σ_j^i can be seen as the probability that type t^i chooses the optimal path j to reach the dummy type. These constraints on Lagrange multipliers are crucial to determine the general solution of the monopolist's problem. The study of the Regular Symmetric Case in the following subsection is an example. We can also notice that in this kind of solution:

$$\lambda(q, t^i) \geq -(1 - \sum_{k \leq i} \pi^k), \text{for all } i, i+1, k \in m,$$

$$\lambda(q, t^i) \geq -\sum_{k \neq i} \sum_j \pi^k \sigma_j^k.$$

Then the part of the distortions in resource allocations due to optimal paths starting from t^k is $-\pi^k$ ($\lambda^k = -\pi^k$). Then the part of the distortions in q^i due to type t^k is:

$$-\pi^k \sigma_j^k \in [-\pi^k, 0].$$

As a consequence, we can write distortions as:

$$q(t_\alpha^i) - \hat{q}(t_\alpha^i) = -\sum_{k \neq i} \sum_j \pi^k \sigma_j^k (t_\alpha^{i+1} - t_\alpha^i)$$

where $\pi^k \sigma_j^k \in]0, \pi^k[$ if there exists at least two optimal paths from t^k going through t^i, $\pi^k \sigma_j^k = \pi^k$ if there is only one such path, and $\pi^k \sigma_j^k = 0$ if no paths runs trough t^i (in this case there exists at least one J such that $t^i = t_J$). This generalizes the result of no distortion at the top of the distribution in each Υ_J.

This confirms a result of Rochet-Chone (98) saying that for any solution we can define several ordered subsets Υ_j defining several sets of agents (in our simple model we do not obtain as they do the set of agents who do no participate and get nothing):

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- a set T^0 (reduced to a singleton):

$$T^0 = \{t_j^0, \text{ for all } j\} = \{t^0\}.$$

where t_j^0 is the lowest type in subset Υ_j. The element of T^0 gets a rent $U\_^0$:

$$U\_^0 = 0.$$

- a set $\tilde{T} = \{t^i\}$ for all i such that:

$$U\_^i > 0,$$
$$q(t^i) \neq \hat{q}(t^i).$$

- as set $\bar{T}$

$$\bar{T} = \{\bar{t}_j, \text{for all} j\},$$

. where $\bar{t}_j$ is the highest type in subset Υ_j. Every element in $\bar{T}$ is such that:

$$U\_^{-j} > 0,$$
$$q(\bar{t}_j) = \hat{q}(\bar{t}_j).$$

5.4 The Regular Symmetric Case in the Equivalent Problem

The monopolist produces two goods with the following cost function:

$$C(q) = \frac{1}{2}(q_1^2 + q_2^2)$$

and wants to sells these two goods to a heterogenous population of four type: We denote these types by letter $i = A, B, C, D$.

$$
\begin{aligned}
t^A &= (t_1^l, t_2^l), & (\pi^A), \\
t^B &= (t_1^h, t_2^l), & (\pi^B), \\
t^C &= (t_1^h, t_2^h), & (\pi^C), \\
t^D &= (t_1^l, t_2^h), & (\pi^D),
\end{aligned}
$$

and $t_\alpha^h - t_\alpha^l = \Delta t_\alpha$, for $\alpha = 1, 2$. Buyers utilities are quasilinear:

$$
\begin{aligned}
U^i &= u(t^i, q_1, q_2) - p(q_1, q_2) - E, \\
u(t^i, q_1, q_2) &= t_1^i q_1^i + t_2^i q_2^i, \\
p^i q^i &= p_1^i q_1^i + p_2^i q_2^i.
\end{aligned}
$$

This solution is such that, C is attracted to B and D and A attracts B and D. We can then define two optimal paths from C to A, one running through B, the other through D. This defines $\gamma_1^C = \{C \rightarrow B \rightarrow A\}$ and $\gamma_2^C = \{C \rightarrow D \rightarrow A\}$. Consequently, we can define two ordered subsets $\Upsilon_1 = \{t^A, t^B, t^C\}$ and $\Upsilon_2 = \{t^A, t^D, t^C\}$ and two expressions for $U\_^C$:

$$
\begin{aligned}
U^C(\gamma_1^C) &= \Delta t_2 q_2^B U\_^B, \\
U^C(\gamma_2^C) &= \Delta t_1 q_1^D + U\_^D.
\end{aligned}
$$

as B and D are immediate successor of C. As A is the immediate successor of B:

$$U\_^B = \Delta t_1 q_1^A,$$

and also the immediate successor of D:

$$U\_^D = \Delta t_2 q_2^A.$$

Then:

$$U^C(\gamma_1^C) = \Delta t_2 q_2^B + \Delta t_1 q_1^A,$$
$$U^C(\gamma_2^C) = \Delta t_1 q_1^D + \Delta t_2 q_2^A.$$

In this case the monopolist problem can be written as:

$$Max \sum_i \pi^i (u(t^i, q^i) - C(q^i) - U\_^i)$$

$$s/c: U\_^A = 0, (\lambda^A),$$
$$: U\_^B = \Delta t_1 q_1^A, (\lambda^B),$$
$$: U\_^D = \Delta t_2 q_2^A, (\lambda^D),$$
$$: U\_^C = \Delta t_2 q_2^B + \Delta t_1 q_1^A, (\lambda_1^C),$$
$$: U\_^C = \Delta t_1 q_1^D + \Delta t_2 q_2^A.(\lambda_2^C).$$

The constraint on $U\_^C$ can also be written as:

$$U\_^C = \sigma_1 U^C(\gamma_1^C) + \sigma_2 U^C(\gamma_2^C),$$
$$\sigma_1 + \sigma_2 = 1,$$
$$\sigma_1 = \sigma.$$

The first order conditions give:

$$\frac{\partial L}{\partial U^i} = -\pi^i - \sum_j \lambda_j^i = 0, \text{ for all } i,$$

$$\Longleftrightarrow \lambda^A = -\pi^A,$$
$$\Longleftrightarrow \lambda^B = -\pi^B,$$
$$\Longleftrightarrow \lambda^D = -\pi^D,$$
$$\Longleftrightarrow \lambda_1^C + \lambda_2^C = -\pi^C,$$

and

$$\frac{\partial L}{\partial q_\alpha^i} = \pi^i \frac{\partial S(t^i, q^i)}{\partial q_\alpha^i} + \sum_{k \neq i} \sum_j \lambda_j^k \frac{\partial U^k(\gamma_j^k)}{\partial q_\alpha^i} = 0, \text{ for all } i \text{ and } \alpha = 1, 2$$

$$\iff \frac{\partial L}{\partial q_1^A} = \pi^A(t_1^A - q_1^A) + (\lambda^B + \lambda_1^C)\Delta t_1 = 0,$$

$$\iff \frac{\partial L}{\partial q_2^A} = \pi^A(t_2^A - q_2^A) + (\lambda^D + \lambda_2^C)\Delta t_2,$$

$$\iff \frac{\partial L}{\partial q_1^B} = \pi^B(t_1^B - q_1^B) = 0,$$

$$\iff \frac{\partial L}{\partial q_2^B} = \pi^B(t_2^B - q_2^B) + (\lambda_1^C)\Delta t_2 = 0,$$

$$\iff \frac{\partial L}{\partial q_1^C} = \pi^C(t_1^C - q_1^C) = 0,$$

$$\iff \frac{\partial L}{\partial q_2^C} = \pi^C(t_2^C - q_2^C) = 0,$$

$$\iff \frac{\partial L}{\partial q_1^D} = \pi^D(t_1^D - q_1^D) + (\lambda_2^C)\Delta t_1 = 0,$$

$$\iff \frac{\partial L}{\partial q_2^D} = \pi^D(t_2^D - q_2^D) = 0.$$

To define the solution, we have to determine the value of the non positive Lagrange multipliers. We still have two unknowns, λ_1^C, λ_2^C and only one equation $\lambda_1^C + \lambda_2^C = -\pi^C$. The missing equation is obtained by:

$$U^C(\gamma_1^C) = U^C(\gamma_2^C)$$
$$\iff \Delta t_2 q_2^B + \Delta t_1 q_1^A = \Delta t_1 q_1^D + \Delta t_2 q_2^A,$$
$$\iff \Delta t_1(q_1^D - q_1^A) = \Delta t_2(q_2^B - q_2^A).$$

We write quantity as functions of λ_1^C and define its value with the above equation: if paths γ_1^C and γ_2^C are both optimal they provide the same rent.

$$q_1^A = t_1^A + \frac{(-\pi^B + \lambda_1^C)}{\pi^A}\Delta t_1,$$

$$q_2^A = t_2^A + \frac{(-\pi^D - \pi^C - \lambda_1^C)}{\pi^A}\Delta t_2,$$

$$q_2^B = t_2^B + \frac{\lambda_1^C}{\pi^B}\Delta t_2,$$

$$q_1^D = t_1^D + \frac{(-\pi^C - \lambda_1^C)}{\pi^D}\Delta t_1,$$

Solving $\Delta t_1(q_1^D - q_1^A) = \Delta t_2(q_2^B - q_2^A)$ we obtain:

$$\lambda_1^C = -[\frac{\pi^B + \pi^C}{\pi^D}\Delta t_1^2 + \frac{1}{\pi^A}\Delta t_2^2]/[(\frac{1}{\pi^A} + \frac{1}{\pi^D})\Delta t_1^2 + (\frac{1}{\pi^A} + \frac{1}{\pi^B})\Delta t_2^2].$$

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This defines a solution if all λ_j^i are non positive. We obtain the condition already found in chapter 2 according to the non positivity of the Lagrange multipliers:

$$\pi^A \pi^C - \pi^B \pi^D > -\frac{\Delta t_2^2}{\Delta t_1^2} \pi^D (\pi^C + \pi^D).$$

The other conditions that must be checked by the model are such that: If type t^i is attracted by its immediate successor t^{i-1} we have:

$$U\_^i - U\_^{i-1} = (t^i - t^{i-1}) q^{i-1},$$

and if t^{i-1} is not attracted to t^i we have:

$$U\_^{i-1} - U\_^i \geq (t^{i-1} - t^i) q^i,$$
$$\Longleftrightarrow U\_^i - U\_^{i-1} < (t^i - t^{i-1}) q^i,$$
$$\Longleftrightarrow (t^i - t^{i-1}) q^{i-1} < (t^i - t^{i-1}) q^i,$$

and we obtain, as in chapter 2:

$$\pi^A \pi^C - \pi^B \pi^D < \frac{\pi^B \pi^D}{\pi^A}.$$

In this solution, $q_1^B, q_1^C, q_2^C, q_2^D$ are equal to the optimal resource allocation. $q_1^A, q_2^A, q_2^B, q_1^D$ are downward distorted. The distortions D_α^i are:

$$D_1^A = \frac{(-\pi^B + \lambda_1^C)}{\pi^A} \Delta t_1 \in \left] \frac{(-\pi^B - \pi^C)}{\pi^A} \Delta t_1, \frac{-\pi^B}{\pi^A} \Delta t_1 \right[,$$

$$D_2^A = \frac{(-\pi^D - \pi^C - \lambda_1^C)}{\pi^A} \Delta t_2 \in \left] \frac{(-\pi^D - \pi^C)}{\pi^A} \Delta t_2, \frac{-\pi^D}{\pi^A} \Delta t_2 \right[,$$

$$D_2^B = \frac{\lambda_1^C}{\pi^B} \Delta t_2 \in \left] -\frac{\pi^C}{\pi^B} \Delta t_2, 0 \right[,$$

$$D_1^D = \frac{(-\pi^C - \lambda_1^C)}{\pi^D} \Delta t_1 \in \left] \frac{-\pi^C}{\pi^D} \Delta t_1, 0 \right[.$$

and for all $i = \{A, B, C, D\}$ and $\alpha = \{1, 2\}$, $D_\alpha^i \leq 0$, since for every optimal path defining an ordered subset, we always have:

$$t_\alpha^{i+1} \geq t_\alpha^i, \text{ for all } i, \alpha.$$

We can explain distortions as follows:

- Type t^B is attracted to t^A, and only t^A,

$$t_1^B > t_1^A,$$
$$t_2^B = t_2^A,$$

then the weight of the distortion on q_1^A due to type t^B's attraction is

$$-\pi^B.$$

Type t^D is attracted to t^A, and only t^A,

$$t_1^D = t_1^A,$$
$$t_2^D > t_2^A,$$

then the weight of the distortion on q_2^A (due to type t^D's attraction is

$$-\pi^D.$$

- Type t^C is attracted to t^B, and also t^D. Then the part of the distortion due to type t^C's attraction is

$$-\pi^C.$$

This weight is split between distortions explained by γ_1^C and γ_2^C. This means that we can define distortions as:

$$D_1^A = \frac{(-\pi^B - \sigma\pi^C)}{\pi^A}\Delta t_1,$$
$$D_2^A = \frac{(-\pi^D - \pi^C(1-\sigma))}{\pi^A}\Delta t_2,$$
$$D_2^B = \frac{-\sigma\pi^C}{\pi^B}\Delta t_2,$$
$$D_1^D = \frac{-\pi^C(1-\sigma)}{\pi^D}\Delta t_1,$$

where $\sigma \in\ ]0, 1[$ depends on q,

$$U\_^C = \sigma U^C(\gamma_1^C) + (1-\sigma)U^C(\gamma_2^C),$$

and can be seen as the "probability" that type t^C chooses paths $\gamma_1^C = \{C \rightarrow B \rightarrow A\}$ to reach the dummy type, $(1-\sigma)$ for γ_2^C. This means that a weight $-\sigma\pi^C$ is dedicated to D_2^B and D_1^A and a weight $-(1-\sigma)\pi^C$ is dedicated to D_1^D and D_2^A. Types t^B and t^D have only one path to reach t^A, so the probability that they choose these paths is one. Consequently, the weight $-\pi^B$ is totally dedicated to D_1^A and the weight $-\pi^D$ is totally dedicated to D_2^A.

Even if, on each route, there are only two levels of demand of services, the airline in this case has to propose 3 levels of services on each route. In this particular example, we have the following solution:

$$q_1^C = q_1^B > q_1^D > q_1^A$$
$$q_2^C = q_2^D > q_2^B > q_2^A$$

which means 3 levels of services on each route.

Customers C receive their first best allocation of services on each route. They fly first on routes 1 and 2. Customers B fly first on route 1 and fly "above economy" on route 2. Customers D fly first on route 2 and fly "above economy" on route 1. Customers A fly economy on both routes. We can also think about services that can be provided outside the aircraft to allow the airline to offer the same level of services on board to customers B and A on route 1, and D and A on route 2.

In the following section, we study the set of solutions $s^* = \{a, b...n\}$ already defined in section 4 as cases $\{A,B...N\}$.

6 The Solution (2) and implications for service allocation in the airline industry

In this section we use the set of solutions defined in section 4, in which characteristics are such that:

$$t_1^l = 4, t_1^h = 6,$$
$$\Delta t_1 = 2,$$
$$t_2^l = 4, t_2^h = 5,$$
$$\Delta t_2 = 1,$$

and types are distributed as follows:

$$\pi^A = \pi^C = \frac{\epsilon}{2},$$
$$\pi^B = \pi^D = \frac{(1 - \epsilon)}{2},$$

and

$$\rho \in] -1, 1[.$$

Even if there are only two levels of demand of services (high or low), as the optimal pricing policy requires a form of bundling, the optimal resource allocation often requires 3 levels of services, sometimes 4 on each route.

6.1 Pure Case

A **Pure Case** is a solution such that there is a unique optimal path of length which runs through all of the types defining a unique ordered partition Υ of T. As a consequence, this also defines a unique optimal path for each type and consequently a unique expression for each rent.

Solution i (case I in section 4) is the only Pure Case in the set of solutions. The attractions are as follows: C is attracted to B, who is attracted to D, who is attracted to A. We can then say that $C \succ B \succ D \succ A$. We can thus define:

$$\Upsilon = \{A, D, B, C\}.$$

In this case, we have:

$$U\_^C = \Delta t_2 q_2^B + \Delta t_1 q_1^D - \Delta t_2 q_2^D + \Delta t_2 q_2^A,$$
$$U\_^B = \Delta t_1 q_1^D - \Delta t_2 q_2^D + \Delta t_2 q_2^A,$$
$$U\_^D = \Delta t_2 q_2^A,$$
$$U\_^A = 0.$$

and quantities are:

$$q_1^A = t_1^A,$$

$$q_2^A = t_2^A + \frac{(-\pi^D - \pi^B - \pi^C)}{\pi^A}\Delta t_2$$

$$q_1^D = t_1^D + \frac{(-\pi^B - \pi^C)}{\pi^D}\Delta t_1,$$

$$q_2^D = t_2^D + \frac{\pi^C + \pi^B}{\pi^D}\Delta t_2,$$

$$q_1^B = t_1^B,$$

$$q_2^B = t_2^B + \frac{-\pi^C}{\pi^B}\Delta t_2,$$

$$q_1^C = t_1^C,$$

$$q_2^C = t_2^C.$$

This solution is singular as a quantity is upward distorted. As distortions depend on the predecessor's type, q_2^D is upward distorted: B is attracted to D so distortions in q_α^D are positive when $t_\alpha^D > t_\alpha^B$ and negative otherwise:

$$t_1^D < t_1^B \implies D_1^D < 0,$$

$$t_2^D > t_2^B \implies D_2^D > 0.$$

As a consequence,

$$q_1^C = q_1^B > q_1^A > q_1^D,$$

$$q_2^D > q_2^C > q_2^B > q_2^A.$$

Again in this case, customers C fly first on both routes. Surprisingly, customers D fly "above first" on route 2 and economy on route 1. Customers B fly first on route one and "above economy" on route 2. Customer A fly economy on route 2 and "above economy" on route 2.

6.2 Almost Pure Case

An **Almost Pure Case** is a solution such that there is a single optimal paths to compute the rent of each type. There exist several distinct optimal paths such that every type has one and only optimal path running through it.

Solution c (case C, Regular Asymmetric Case in section 4) is the only Almost Pure Case in the set of solutions. The attractions are as follows: C is attracted to D, who is attracted to A, and B is attracted to A. We can then say that $C \succ D \succ A$ and $B \succ A$. We can thus define: $\Upsilon_1 = \{A, D, C\}$ and $\Upsilon_2 = \{A, B\}$ defining: $\gamma^C = \{C \to D \to A\}, \gamma^D = \{D \to A\}$ and $\gamma^B = \{B \to A\}$.

The set of optimal rents is accordingly as follows:

$$U\_^C = \Delta t_1 q_1^D + \Delta t_2 q_2^A,$$

$$U\_^B = \Delta t_2 q_1^A,$$

$$U\_^D = \Delta t_2 q_2^A,$$

$$U\_^A = 0.$$

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This solution is regular and quantities are:

$$q_1^A = t_1^A + \frac{-\pi^B}{\pi^A}\Delta t_2,$$

$$q_2^A = t_2^A + \frac{(-\pi^D - \pi^C)}{\pi^A}\Delta t_2,$$

$$q_1^D = t_1^D + \frac{-\pi^C}{\pi^D}\Delta t_1,$$

$$q_2^D = t_2^D,$$

$$q_1^B = t_1^B,$$

$$q_2^B = t_2^B,$$

$$q_1^C = t_1^C,$$

$$q_2^C = t_2^C.$$

C and B are the highest type in the respective ordered subsets Υ_1 and Υ_2. As a consequence, C and B obtain their first best allocations.

we have the following solution:

$$q_1^C = q_1^B > q_1^D > q_1^A$$

$$q_2^C = q_2^D > q_2^B > q_2^A$$

which means 3 levels of services on each route.

Customers C and B receive their first best allocation of services on each route. Customers C fly first on routes 1 and 2. Customers B fly first on route 1 and fly "above economy" (at his first best level) on route 2. Customers D fly first on route 2 and fly "above economy" on route 1. Customers A fly economy on both routes.

6.3   Regular and Completely Ordered

Such a solution does not exist since we have to rank t^B and t^D. To be able to do so, whether there exists an attraction between them or they can reach each other through t^C without involving any transverse binding ICC. In both cases there is upward distortions: whether t^B or t^D attracts the other, quantities allocated to the attracted one are distorted, one upwards and one downwards as:

$$t_1^B > t_1^D,$$

$$t_2^D > t_2^B;$$

if t^B or t^D can reach the other one through t^C implies that q^C is upward distorted as:

$$t_1^C > t_1^D,$$

$$t_2^C > t_2^B.$$

6.4   Regular and Partially Ordered

Solutions d, e and f, respectively Regular Symmetric Case and the Separable Case, are regular and allow partially type ordering.

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For solution d, see the previous Section.

In solution e, C is attracted to B and D and A attracts B, D and C. We can then define three optimal paths from C to A, one running through B, the other through D, and a third one going directly to A. This defines $\gamma_1^C = \{C \to B \to A\}$, $\gamma_2^C = \{C \to D \to A\}$ and $\gamma_3^C = \{C \to A\}, \gamma^D = \{D \to A\}, \gamma^B = \{B \to A\}$. Consequently, we can define three ordered subsets $\Upsilon_1 = \{t^A, t^B, t^C\}, \Upsilon_2 = \{t^A, t^D, t^C\}$ and $\Upsilon_3 = \{t^A, t^C\}$ and three expressions for $U\_^C$.

In solution f, C is attracted to D and A, and A attracts B, D and C. We can then define three optimal paths from C to A, one running through B, the other through D, and a third one going directly to A. This defines $\gamma_1^C = \{C \to D \to A\}$, $\gamma_2^C = \{C \to A\}, \gamma^D = \{D \to A\}, \gamma^B = \{B \to A\}$. Consequently, we can define two ordered subsets $\Upsilon_1 = \{t^A, t^D, t^C\}, \Upsilon_2 = \{t^B, t^C\}$ and two expressions for $U\_^C$.

Solutions d,e and f defines a type ordering for each good: for the good 1, $C = B \succ D \succeq A$ and for good 2: $C = D \succ B \succeq A$.

Again, we obtain the following solution:

$$q_1^C = q_1^B > q_1^D > q_1^A$$
$$q_2^C = q_2^D > q_2^B > q_2^A$$

which means 3 levels of services on each route.

Customers C receive their first best allocation of services on each route. They fly first on routes 1 and 2. Customers B fly first on route 1 and fly "above economy" on route 2. Customers D fly first on route 2 and fly "above economy" on route 1. Customers A fly economy on both routes. We can also think about services that can be provided outside the aircraft to allow the airline to offer the same level of services on board to customers B and A on route 1, and D and A on route 2.

6.5 Singular and Completely Ordered

A pure case belongs to this class of solutions.

Solutions a, b, h, i, j, k, m are singular (upward distortions) and completely ordered (there exists an ordered subset Υ_j of four types).

In this set of solutions there are two possible type ordering:

$$C \succ B \succ D \succ A \text{ for solutions } i, j, k,$$
$$B \succ C \succ D \succ A \text{ for solutions } a, b, h.$$

This can be explained as follows:

- solutions a, b, h occur for low values of ϵ equivalent to low proportions of types t^C and t^A and high proportions of types t^B and t^D. It is in the monopolist's interest to extract maximum surplus from types t^B and thus sell them their first best allocations. Even if $\pi^B = \pi^D$ and whatever the solution, neither D is the highest type nor D is superior to B. This comes from the parameters of the model, $\Delta t_1 > \Delta t_2$.

In this case we have,

$$q_1^C = q_1^B > q_1^A > q_1^D,$$
$$q_2^D > q_2^C > q_2^B > q_2^A.$$

Again, customers C fly first on both routes. Surprisingly, customers D fly "above first" on route 2 and economy on route 1. Customers B fly first on route one and "above economy" (at their first best level) on route 2. Customer A fly economy on route 2 and "above economy" on route 2.

- solutions i, j, k are such that B is attracted to D. This enables to rank them and defines the unique and expected type ordering $C \succ B \succ D \succ A$, where C is the highest as $t_\alpha^C \geq t_\alpha^i$ for all α, i. Then B is bigger than D as B has more impact on distortions than D since $\Delta t_1 > \Delta t_2$. At last A is the lowest type as $t_\alpha^A \leq t_\alpha^i$ for all α, i.

In this case we have,

$$q_1^C = q_1^B > q_1^A > q_1^D,$$
$$q_2^D > q_2^C > q_2^B > q_2^A.$$

Again, customers C fly first on both routes. Surprisingly, customers D fly "above first" on route 2 and economy on route 1. Customers B fly first on route one and "above economy" on route 2. Customer A fly economy on route 2 and "above economy" on route 2.

6.6 Singular and Partially Ordered

Solution l is such that:

$$\gamma^C = \{C \rightarrow D \rightarrow A\},$$
$$\gamma^D = \{D \rightarrow A\},$$
$$\gamma_1^B = \{B \rightarrow D \rightarrow A\},$$
$$\gamma_2^B = \{B \rightarrow A\},$$

defining:

$$\Upsilon_1 = \{A, D, C\},$$
$$\Upsilon_2 = \{A, D, B\}.$$

B and C obtain their first best allocations while q_2^D is upwards distorted and q_1^D, q_1^A, q_2^A are downwards distorted. Even we can rank B and D we cannot rank C and D and define a unique type ordering. We have:

$$T^0 = \{t^A\},$$
$$\bar{T} = \{t^D\},$$
$$\bar{T} = \{t^C, t^B\}.$$

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In this case we have,

$$q_1^C = q_1^B > q_1^A > q_1^D,$$
$$q_2^D > q_2^C > q_2^B > q_2^A.$$

Again, customers C fly first on both routes. Surprisingly, customers D fly "above first" on route 2 and economy on route 1. Customers B fly first on route one and "above economy" (at their first best level) on route 2. Customer A fly economy on route 2 and "above economy" on route 2.

6.7 Special cases

Solutions n and g as two types attract each other, B and C.

This kind of solution means that there exists two types such that:

$$U\_^i - U\_^j = (t^i - t^j)q^i,$$
$$U\_^j - U\_^i = -(t^i - t^j)q^j,$$
$$\implies q_\alpha^i = q_\alpha^j \text{ for all } (t_\alpha^i - t_\alpha^j) \neq 0.$$

If $(t_\alpha^i - t_\alpha^j) > 0$, this means that q_α^i is upwards distorted and q_α^j is downwards distorted, then we have:

$$q_\alpha^i > \hat{q}_\alpha^i > \hat{q}_\alpha^j > q_\alpha^j,$$

which cannot be satisfied with:

$$q_\alpha^i = q_\alpha^j.$$

As a consequence, $q_\alpha^i = q_\alpha^j = 0$.

In solution g we can define the following ordered subsets:

$$\Upsilon_1 = \{C, B, A\}$$
$$\implies C \succ B \succ A,$$

$$\Upsilon_2 = \{B, C, D, A\}$$
$$\implies B \succ C \succ D \succ A.$$

In this particular case where B is at the same time the immediate successor, in Υ_1, and the immediate predecessor, in Υ_2, of C . We have:

$$U\_^C - U\_^B = \Delta t_2 q_2^B,$$
$$U\_^B - U\_^C = -\Delta t_2 q_2^C,$$

and consequently:

$$q_2^C = q_2^B,$$
$$= q_2^A.$$

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In this solution optimal paths γ_j^i define the rents of B and C are as follows:

$$U\_^C = \Delta t_2 q_2^B + \Delta t_1 q_1^A, \text{with probability } \sigma_1^C,$$
$$= \Delta t_2 q_2^A + \Delta t_1 q_1^A, \text{with probability } \sigma_2^C,$$
$$= \Delta t_2 q_2^A + \Delta t_1 q_1^D, \text{with probability } \sigma_3^C,$$
$$U\_^B = \Delta t_1 q_1^A, \text{with probability } \sigma_1^B,$$
$$= -\Delta t_2 q_2^C + \Delta t_2 q_2^A + \Delta t_1 q_1^A, \text{with probability } \sigma_2^B,$$
$$= -\Delta t_2 q_2^C + \Delta t_2 q_2^A + \Delta t_1 q_1^D, \text{with probability } \sigma_3^B.$$

As $\gamma_2^C \subset \gamma_2^B$ and $\gamma_3^C \subset \gamma_3^B$ we have:$\sigma_2^C = \sigma_2^B$ and $\sigma_3^C = \sigma_3^B$ and consequently: $\sigma_1^C = \sigma_1^B$. Then we have:

$$q_2^C = t_2^C + \Delta t_2 \frac{(\sigma_2^B + \sigma_3^B)\pi^B}{\pi^C} + \Delta t_2 \frac{\sigma_1^B \pi^C}{\pi^C},$$
$$q_2^B = t_2^B - \Delta t_2 \frac{\sigma_1^B \pi^C}{\pi^B} - \Delta t_2 \frac{(\sigma_2^B + \sigma_3^B)\pi^B}{\pi^B}$$

where the second term of each distortion is explained by mutual attractions, which means according to distortions that are usually computed as:

$$q(t_\alpha^i) - \hat{q}(t_\alpha^i) = -\sum_{k \neq i}\sum_j \pi^k \sigma_j^k (t_\alpha^{i+1} - t_\alpha^i),$$

are computed:

$$q(t_\alpha^i) - \hat{q}(t_\alpha^i) = -\sum_{k}\sum_j \pi^k \sigma_j^k (t_\alpha^{i+1} - t_\alpha^i),$$

that we make the sum for all k as $q_\alpha^k = q_\alpha^i$ when k and i attract each other and $t_\alpha^k - t_\alpha^i \neq 0$. $q_2^C = q_2^B$ implies:

$$\frac{(\sigma_2^B + \sigma_3^B)\pi^B}{\pi^C} + \frac{\sigma_1^B \pi^C}{\pi^B} = 0$$

which is impossible. If we neglect closed paths (and mutual attractions), using:

$$q(t_\alpha^i) - \hat{q}(t_\alpha^i) = -\sum_{k \neq i}\sum_j \pi^k \sigma_j^k (t_\alpha^{i+1} - t_\alpha^i),$$

this second part of the distortions does not appear and the condition becomes:

$$\frac{(\sigma_2^B + \sigma_3^B)\pi^B}{\pi^C} + \frac{\sigma_1^B \pi^C}{\pi^B} = -1$$

which is also impossible. This defines a solution in which the monopolist only sells good 1 as:

$$q_2^C = q_2^B = q_2^A = 0.$$

In this case:

$$T^0 = \{t^A, t^D\} = \{t_1^l\},$$
$$\tilde{T} = \emptyset,$$
$$\bar{T} = \{t^B, t^C\} = \{t_1^h\}$$

as in the classic one dimensional case of course since only one good is produced. This does not means that good 2 is not profitable. This means that there is no optimal mechanism enabling the monopolist to fully apply his monopoly power and he is better off selling both goods independently.

We then obtain the following solution (see separable case in section 4),

$$q_1^C = q_1^B > q_1^D = q_1^A,$$
$$q_2^C = q_2^D > q_2^B = q_2^A.$$

Again, customers C fly first on both routes. Customers D fly first on route 2 and economy on route 1. Customers B fly first on route one and economy on route 2. Customer A fly economy on both routes.

Solution n is equivalent as B and C attract each other implying:

$$q_2^C = q_2^B,$$

implying the sum of strictly positive terms to be negative,

$$\frac{\pi^C}{\pi^B} + \frac{\pi^B}{\pi^C} = -1$$

if we neglect mutual attraction, which is of course impossible. Computing utilities:

$$U\_^C = \Delta t_2 q_2^A + \Delta t_1 q_1^A, \text{with probability } \sigma_1^C,$$
$$= \Delta t_2 q_2^A + \Delta t_1 q_1^D, \text{with probability } \sigma_2^C,$$
$$U\_^B = -\Delta t_2 q_2^C + \Delta t_2 q_2^A + \Delta t_1 q_1^A, \text{with probability } \sigma_1^B,$$
$$= -\Delta t_2 q_2^C + \Delta t_2 q_2^A + \Delta t_1 q_1^D, \text{with probability } \sigma_2^B,$$

as C is attracted to B but cannot reach A as B is not attracted to A. This creates a closed paths, $C \to B \to C$. Again:

$$q_2^i = 0, \text{ for all } i.$$

We then obtain the same solution as in case g.

In both cases, there is no optimal selling mechanism enabling the monopolist to fully apply his monopoly power. In this case, as we assume that both routes are profitable, the airline will market these routes independantly.

7 Conclusion

In this paper we have derived the complete solution of a two-product monopolist in the 2*2 case with a quadratic cost function and linear preferences. We have seen that a solution with the same qualitative features than the one in dimension one does not exists for all parameters neither for all distributions.

In the case where there is no cross cost parameter, we have discovered four possible solutions depending on the correlation between types, as in Armstrong-Rochet (98), whereas Dana (93) in a different context, but a similar setting, finds only two solutions. One of the most striking

result is the solution for strongly negative correlation, the singular case: there is an upward binding ICC (B towards C and not D towards C because $\Delta t_1 \geq \Delta t_2$) and a transverse one (B towards D because $\Delta t_1 \geq \Delta t_2$). As a consequence, the highest type C receives an upwards distorted allocation, whereas an "intermediary" type, B, gets his first best allocation (and also in the regular asymmetric case). The type who has the highest indirect utility level does not always get his first best allocation(see type C in the singular case), and is not necessarily the only one to get it.

When we take ρ into account several other solutions appear each one having its own properties. We know that D is always attracted to A and never to B and C. The monopolist always captures all the surplus of the lowest type (A) and the others always obtain a strictly positive surplus.

We also show that the bidimensional monopolist's problem has solutions such that:

- the optimal pricing mechanism often requires a form of bundling

- it is sometimes impossible for the monopolist to apply his monopoly power, and he is sometimes better off selling both goods independently,

- if all the quantities served by the monopolist are positive, there is no closed path or mutual attraction and the set of types who get no rent is reduced to a singleton, the dummy type,

- distortions depend on the number of optimal paths and also on their lengths, especially the number of types involved in these optimal paths,

- the sign of the distortions in types t^is allocations only depends on their immediate predecessors,

- the rule of no distortion at the top of the distribution is always satisfied.

In this particular bidimensional setting we succeed in finding the global solution as there are only two arguments, two characteristics and four types. We are also able to solve the problem by maximizing the expected virtual surplus for Pure and Almost Pure cases. In a general multidimensional setting, solving the problem is always feasible as we have enough equations to determine all the unknowns. But to do so we have to be able to answer the question: What is the set of optimal paths that defines the solution?

On the airline side, empirical research is needed on route monopolies. Further research should also be undertaken on network monopolies connecting secondary airports.

8 Graphs and Figures

9 Appendices

9.1 Appendix 1

Conditions on quantities for the Regular Symmetric Case:

$$U^B - U^A = \Delta t_1 q_1^A,$$
$$U^A - U^B \geq -\Delta t_1 q_1^B,$$
$$\Leftrightarrow q_1^B \geq q_1^A.$$

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Figure 1:

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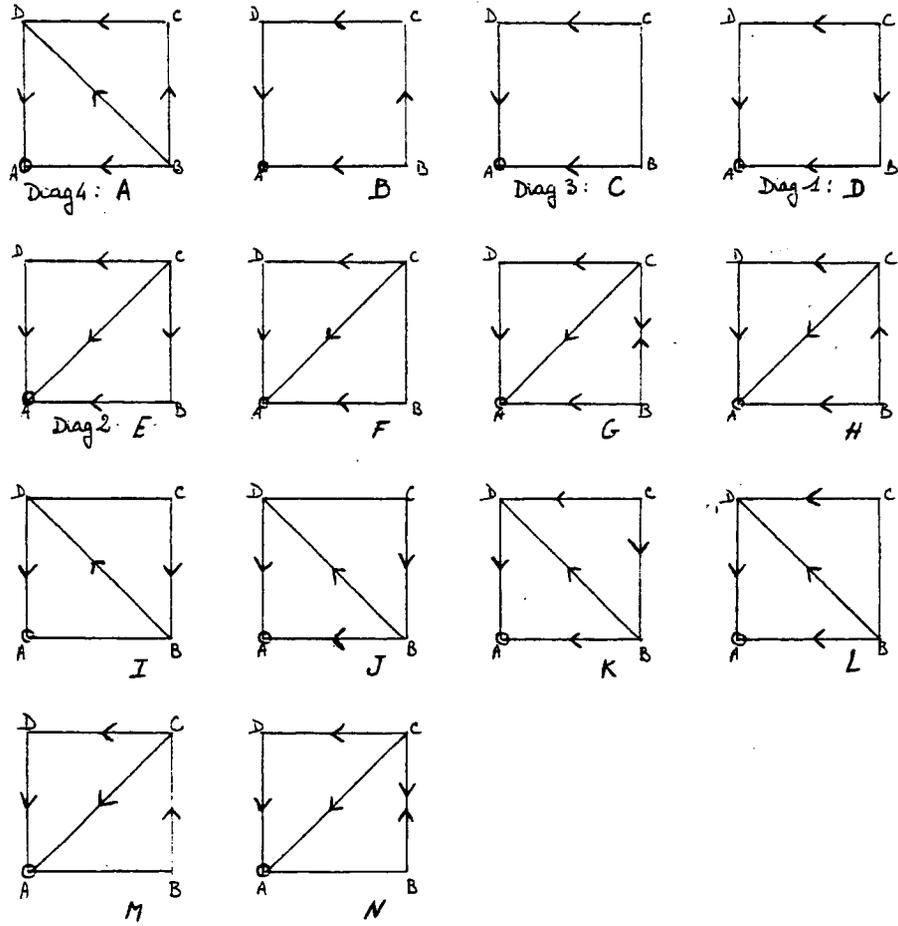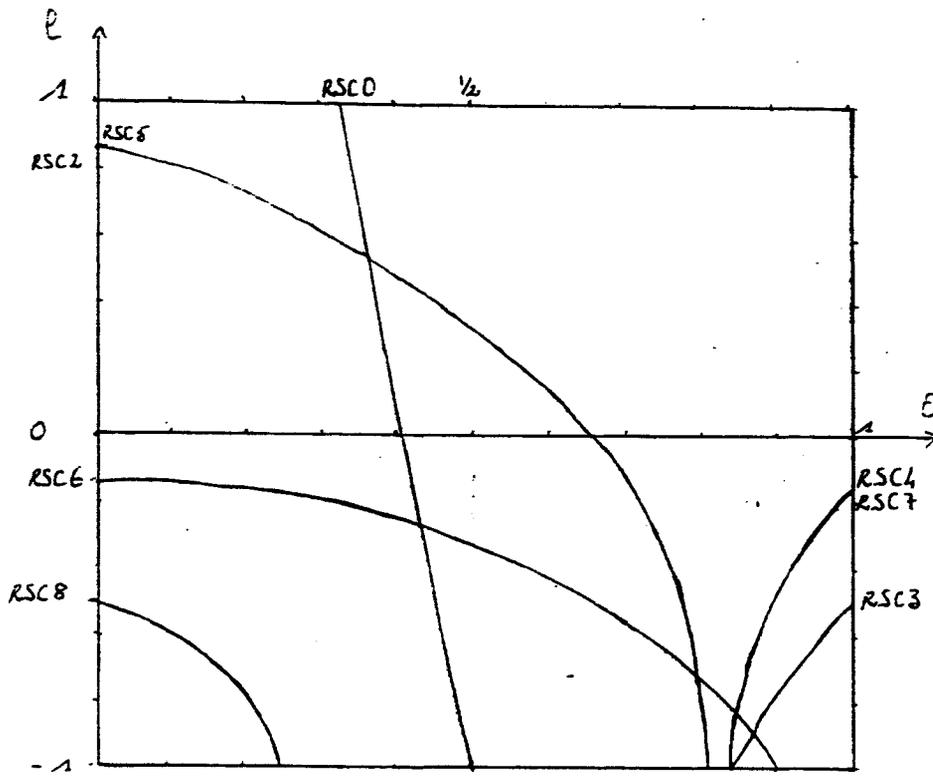
Figure 1

Figure 2:

Figure 2
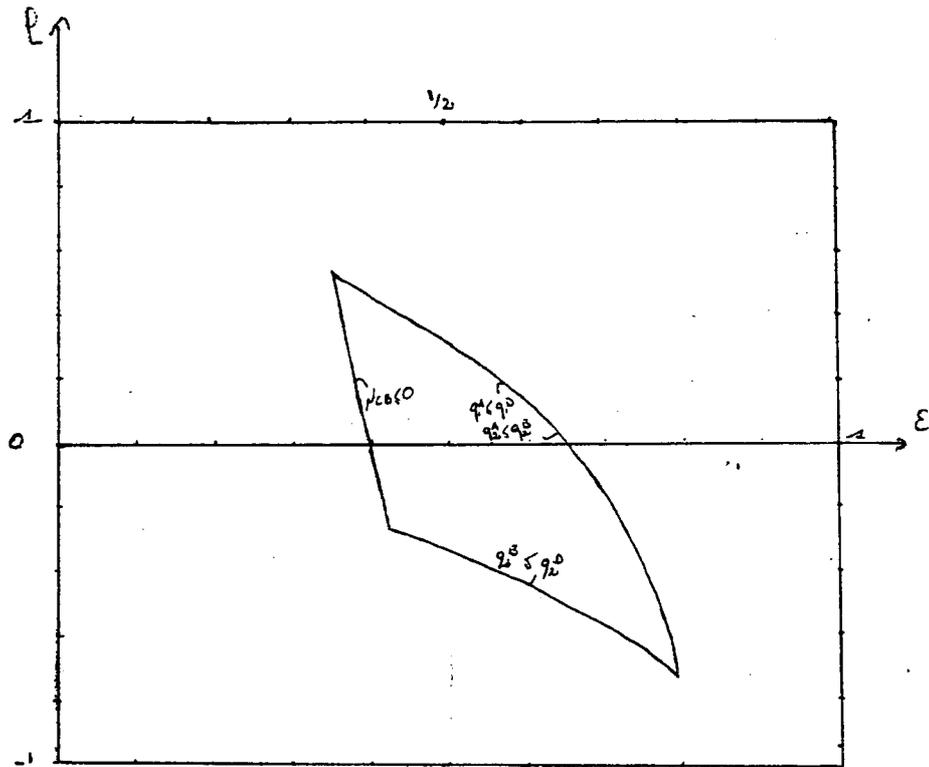
Figure 3:

Figure 3
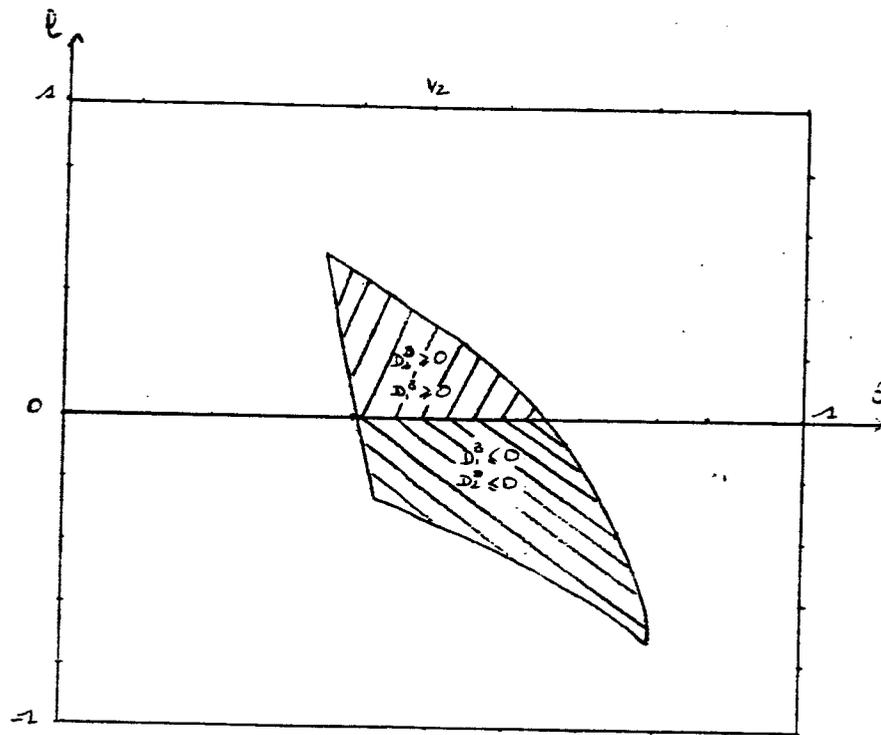
Figure 4:

Figure 4
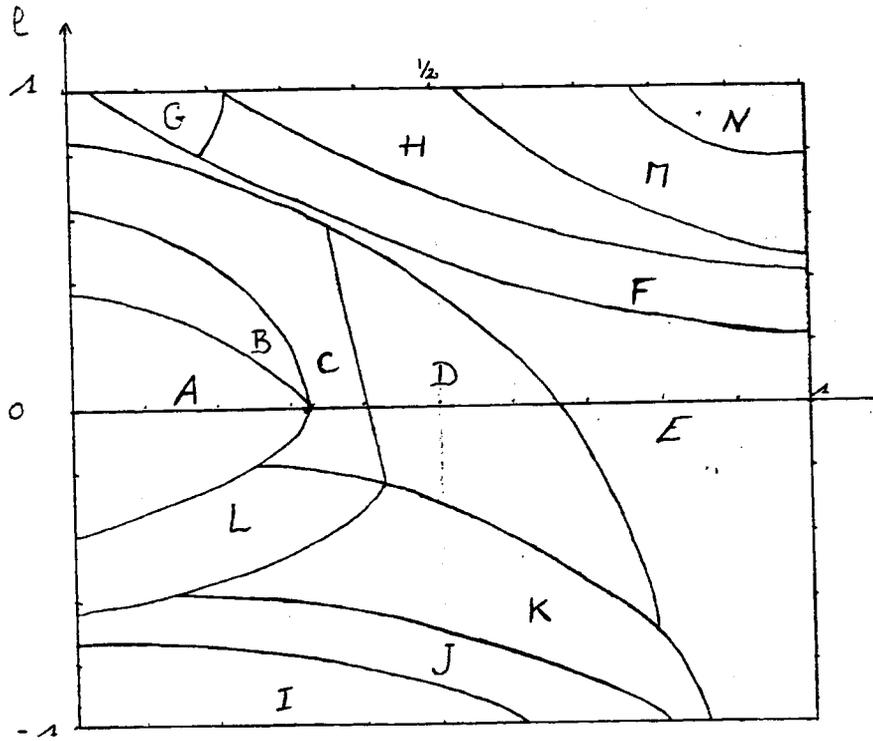
Figure 5:

$$U^D - U^A = \Delta t_2 q_2^A$$

$$,$$

$$U^A - U^D \geq -\Delta t_2 q_2^D$$

$$,$$

$$\Leftrightarrow q_2^D \geq q_2^A$$

$$.$$

$$U^C - U^A = \Delta t_1 q_1^D + \Delta t_2 q_2^A$$

$$U^C - U^A = \Delta t_1 q_1^A + \Delta t_2 q_2^B$$

$$U^C - U^A \geq \Delta t_1 q_1^A + \Delta t_2 q_2^A$$

$$\Leftrightarrow q_1^D \geq q_1^A, \text{et } q_2^B \geq q_2^A.$$

$$U^C - U^A \leq \Delta t_1 q_1^C + \Delta t_2 q_2^C$$

$$U^C - U^B = \Delta t_2 q_2^B$$

$$U^B - U^C \geq -\Delta t_2 q_2^C$$

$$\Leftrightarrow q_2^C \geq q_2^B$$

$$U^C - U^D = \Delta t_1 q_1^D$$

$$U^D - U^C \geq -\Delta t_1 q_1^C$$

$$\Leftrightarrow q_1^C \geq q_1^D$$

$$U^B - U^D = \Delta t_1 q_1^D - \Delta t_2 q_2^B$$

$$U^B - U^D \geq \Delta t_1 q_1^D - \Delta t_2 q_2^D$$

$$\Leftrightarrow q_2^D \geq q_2^B$$

$$U^D - U^B \geq -\Delta t_1 q_1^B + \Delta t_2 q_2^B$$

$$\Leftrightarrow q_1^B \geq q_1^D$$

9.2 Appendix 2

We write here the F.O.C of the problem in the 2*2 case when buyers are uniformly distributed. In this case we obtain the following equations for the optimal quantities:

$$q_1^A = \frac{1}{(1-\rho^2)}[t_1^A + 2\Delta t_1 \frac{\mu_{BA}+\mu_{CA}}{\epsilon} - \rho(t_2^A + 2\Delta t_2 \frac{-\mu_{CA}-\mu_{DA}}{\epsilon})]$$
$$q_1^B = \frac{1}{(1-\rho^2)}[t_1^B + 2\Delta t_1 \frac{-\mu_{AB}-\mu_{DB}}{1-\epsilon} - \rho(t_2^B + 2\Delta t_2 \frac{-\mu_{CB}-\mu_{DB}}{1-\epsilon})]$$
$$q_1^C = \frac{1}{(1-\rho^2)}[t_1^C + 2\Delta t_1 \frac{-\mu_{AC}-\mu_{DC}}{\epsilon} - \rho(t_2^C + 2\Delta t_2 \frac{\mu_{BC}+\mu_{AC}}{\epsilon})]$$
$$q_1^D = \frac{1}{(1-\rho^2)}[t_1^D + 2\Delta t_1 \frac{\mu_{BD}+\mu_{CD}}{1-\epsilon} - \rho(t_2^D + 2\Delta t_2 \frac{\mu_{AD}+\mu_{BD}}{1-\epsilon})]$$
$$q_2^A = \frac{1}{(1-\rho^2)}[t_2^A + 2\Delta t_2 \frac{\mu_{CA}+\mu_{DA}}{\epsilon} - \rho(t_1^A + 2\Delta t_1 \frac{-\mu_{BA}-\mu_{CA}}{\epsilon})]$$
$$q_2^B = \frac{1}{(1-\rho^2)}[t_2^B + 2\Delta t_2 \frac{\mu_{CB}+\mu_{DB}}{1-\epsilon} - \rho(t_1^B + 2\Delta t_1 \frac{\mu_{AB}+\mu_{DB}}{1-\epsilon})]$$
$$q_2^C = \frac{1}{(1-\rho^2)}[t_2^C + 2\Delta t_2 \frac{-\mu_{BC}-\mu_{AC}}{\epsilon} - \rho(t_1^C + 2\Delta t_1 \frac{\mu_{AC}+\mu_{DC}}{\epsilon})]$$
$$q_2^D = \frac{1}{(1-\rho^2)}[t_2^D + 2\Delta t_2 \frac{-\mu_{AD}-\mu_{BD}}{1-\epsilon} - \rho(t_1^D + 2\Delta t_1 \frac{(-\mu_{BD}-\mu_{CD})}{1-\epsilon})]$$

We have the following equations for the Lagrange multipliers of the problem:

$$-\pi^A - \lambda^A - \mu_{AB} - \mu_{AC} - \mu_{AD} + \mu_{BA} + \mu_{CA} + \mu_{DA} = 0,$$
$$-\pi^B - \lambda^B - \mu_{BA} - \mu_{BC} - \mu_{BD} + \mu_{AB} + \mu_{CB} + \mu_{DB} = 0,$$
$$-\pi^C - \lambda^C - \mu_{CA} - \mu_{CB} - \mu_{CD} + \mu_{AC} + \mu_{BC} + \mu_{DC} = 0,$$
$$-\pi^D - \lambda^D - \mu_{DA} - \mu_{DB} - \mu_{DC} + \mu_{AD} + \mu_{BD} + \mu_{CD} = 0.$$

To derive the complete solution we replicate the technic used in section 4. We take a solution and find the frontiers(the conditions on quantities and the sign of μ_{ij}s). We then look for a solution if one of these conditions fails. We then find the binding constraints and then we check the conditions of existence of a solution. We always obtain a system of P equations with P unknowns. We have N equations ($\frac{\partial U}{\partial q}$) and the missing equations are equality conditions on quantities, obtained by examining the attractions and the different possible paths from one type to another. And so on...(see figure 4). This has been done with Mathematica 3.0 (a mathematical software).

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Cooperation of German Airports in Europe – Comparison of different Types by means of an Interdependence-Profile-Model

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Abstract

The limited growth possibilities in the home markets - not the least of which, based on capacity and expansion problems - force the large airport operators to enter into, via partnerships, cooperations and alliances. The German airports already cooperate among one another in different forms.

The purpose of the paper is to examine the structures and possibilities of cooperation among airports in Europe (e.g. Airport Systems, Airport Networks). The experience of German airports with different cooporations and alliances will be also considered.

Finally the forms of cooperations among airports are analysed by means of interdependence-profile-models with different features (mutual dependence, coordination volume, complexity, cooperation profit, value, degree of formalization and temporal frame), in order to find out how high the cooperative attachment of cooperation is to be evaluated.

Keywords: Cooperation, Airport Alliance, Airport System, Airport Network, Airport Holding, Interdependence-Profile-Model, Satellite Airports, Joint Ventures, mutual dependence, coordination volume, complexity, cooperation profit, value, degree of formalization and temporal frame

1. Introduction

The limited growth possibilities in the home markets - not the least of which, based on capacity and expansion problems - force the large airport operators to enter into, via partnerships, cooperations and alliances. The German airports already cooperate among one another in different forms.

The purpose of the paper is to examine the structures and possibilities of cooperation among airports in Europe (e.g. Airport Systems, Airport Networks). The experience of German airports with different cooporations and alliances will be also considered.

Finally the forms of cooperations among airports are analysed by means of interdependence-profile-models with different features (mutual dependence, coordination volume, complexity, cooperation profit, value, degree of formalization and temporal frame), in order to find out how high the cooperative attachment of cooperation is to be evaluated.

2. Different Forms of Cooperations among Airports

For some years airports announced cooperations or partnerships among each other. The number of airports who have partnership shares in other airports, or own other airports, increased too. Some forms of cooperation among airports will be represented at the following:

2.1 Cooperation within Airport Alliance: Cooperation in the Secondary Market and Competition on Primary Market

Cooperation of the airports occur in the most different sections of the airport business. However, a cooperation is also possible in a single field. Airports arranged a free-and-easy-cooperation in some more area of operations, like the cooperation among the south-german airports ("South German Airport Alliance"): Munich, Dresden, Leipzig, Nuremberg and Stuttgart. In this case, it was stressed that a practical cooperation is only striven by mutual investments by protection of independence and without interlacing or fusion of the cooperation partners.

2.2 Cooperations between large Airports and their satellite Airports

In the case of cooperation with ownership stakes, one airport acquires business interests of another airport and takes influence on the business policy and the development of the other one. In Germany airport ownership cooperations can be divided in two ways: ownership stake among a large airport and a small "satellite airport" (Frankfurt - Hahn, Dusseldorf - Gladbach, Munich - Augsburg, Stuttgart - Baden Airport) or a large airport and a distantly located airport (Frankfurt - Saarbruecken and Frankfurt - Hanover).

2.3 Cooperation within Airport Holdings and Airport Systems

The cooperation form of the holding company supports a homogeneous and comprehensive strategic appearance of the partners. The concept of a airport holding company is especially widespread among the European airport systems. The airports of Berlin Schoenefeld, Tegel and Tempelhof are part of the dominating BERLIN BRANDENBURG AIRPORT HOLDING LTD. (BBF). For the members, this holding company takes care of the following tasks: accountancy, controlling, marketing, public relations and environmental control as well as the project control for the Single-Airport Berlin-Brandenburg-International (BBI) and the preparation of the privatisation of the BBF. A few months ago the airports Leipzig-Halle and Dresden became the CENTRAL-GERMAN-AIRPORT-HOLDING.

2.4 Cooperation within Airport Networks

This is a further form of the cooperation with ownership stakes by a Non-Airport-enterprise - An example for this are the activities of the 100 percent subsidiary of the building combine HOCHTIEF LIMITED COMPANY, the HOCHTIEF AirPort Ltd. This enterprise invests in airports, develops and operates them like the airport Athens-Spata. The project of the new international Athens Airport was constructed by a consortium as BOT-Model. Since 1997 the HOCHTIEF AirPort Company tenders in cooperation with the Irish airport management company AERRIANTA INTERNATIONAL for privatisation of airports. In this case, they received the acceptances of a bid for minority stakes at the two privatisation in part of airports in Germany, Dusseldorf and Hamburg.

The airport network of the HOCHTIEF AirPort, that is the investment to commerce airports, exists in present 39,9 percent at the ATHENS INTERNATIONAL AIRPORT S.A. and together with AerRIANTA 50 percent at the Airport Dusseldorf and 36 percent (with an option of further 13 percent in the next years) at the Airport Hamburg. Furthermore this airport com-

pound have also indirect the investment on the Airport Moenchengladbach with 70 percent, because its included in the Airport Dusseldorf stake.

For HOCHTIEF AirPort Company is - after the integration of the airports into their airport network - one of the aims the creation of additional profit potentials from compound effects ("Economies of scope") for the member airports. On account of the view into the processes, the organization and the cost structures of "their" different airports the stake owner can perform optimal Benchmarking. Efficiency gaps of the airports can be filled systematically by the continuous comparison of the processes and the means.

2.5 Cooperation within Joint Ventures (e.g. PANTARES ALLIANZ)
The limited growth possibilities in the home markets (not in the end on account of capacity and expansion problems) force the large airport operator companies via partnerships up to cooperations and stake ownerships in the global field. Example is the cooperation between the Schiphol group (Airport Amsterdam) and the formerly hard competitor Airport Frankfurt (FRAPORT). In November 2000 this first alliance between two international hub airports was announced officially under the market appearance of the common subsidiary PANTARES.

3. Analysis of different Airport Cooperations

For enterprises it is in practice of great importance which kind of attachment, which interdependences on the one hand exist to the cooperation partner and on the other hand exist between cooperation activity and other enterprise activity. By means of an interdependence profile, will be attempted in the following to illustrate the importance of airport cooperations by some features (mutual dependence, coordination volume, complexity, cooperation profit, weight, degree of formalization and temporal frame). For this purpose, some cooperation forms between airports were analysed by means of the above criteria. The aim was to find out how highly the cooperative attachment of cooperation is to be evaluated. A bipolar continuum seems apt for this purpose. The interdependence section of TROENDLE (illustration 1) is taken as a basis for this model. On a scale from zero (low) to one hundred (high): At one end we find the simplest market transaction/exchange, which can not yet be taken as cooperation, and at the other end a complete fusion of the partners which cannot be designated as cooperation any more.

Illustration 1: Interdependence profile by TROENDLE

Interdependence Profile Model of Cooperations


```
Mutual Dependence
Coordination Volume
Complexity
Cooperation Profit
Value
Degree of Formalization
Temporal Frame

        0   10   20   30   40   50   60   70   80   90   100
        low  ———>  cooperative attachment  ———>  high
        (individual)                              (pooled)
```
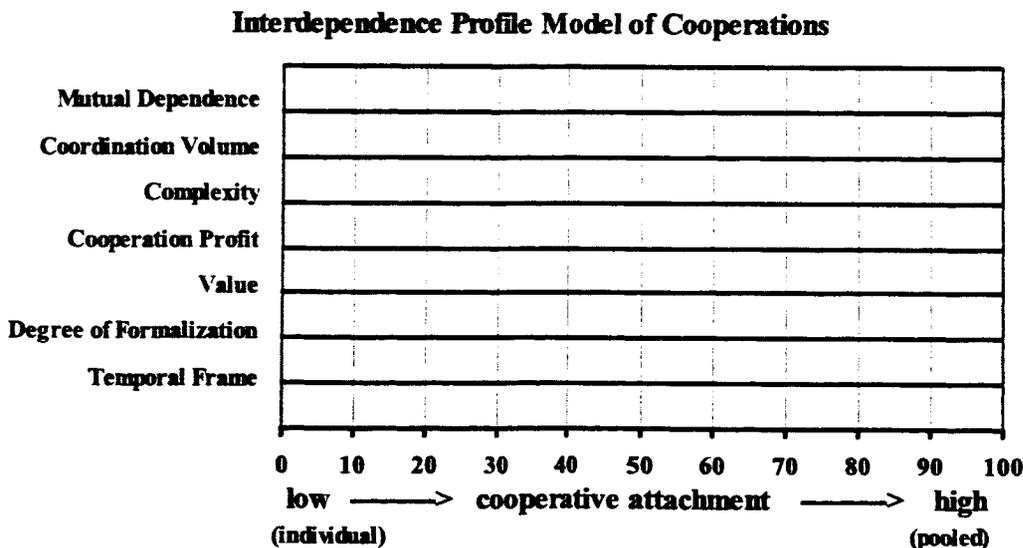
The individual positions between these extremes show the extensity of the cooperation relationships (small - high) by means of the criteria *mutual dependence, coordination volume, complexity, cooperation profit origin* (here: individual - pooled), *value, degree of formalization* and *temporal frame*.

The individual dimensions of the interdependence section by TROENDLE are to be interpreted as follows:

- The more distinctly the criterion of *mutual dependence* is developed, the larger is the attachment between the enterprises. The smaller the substituability of service produced by the cooperation partners is, accordingly, the greater is dependence.

- The *coordination volume* indicates how extensive the communication requirements are in order to match the business actions. The more frequent and more extensively the partners must coordinate their transactions, the more certainly one can speak of cooperation with fare-reaching mutual adaptation measures. The coordination volume depends largely on the decision rules and possible capital majorities.

- The *complexity* of a cooperation is an indicator of the number and interdependence of enterprise functions which are concerned by cooperation. Complexity is very high, for instance, during the foundation of a joint venture, but small in the case of a pure agreement about a standardization of a product.

- *Cooperation profit* can either result in commonly, and must then be divided up between cooperation partners ("pooling"), or it results individually. However, a combination of both kinds (e.g. Joint Venture) is also conceivable if the partners supply cooperating enterprise individually. A *cooperation profit* resulting commonly corresponds more to an intense cooperation than a reciprocal cooperation with which the profit results individually because of exchange.

- Furthermore, the *value* of a cooperation is important for an enterprise. The more larger the sales part respectively dividend, or the resources put into this cooperation are, the greater is the importance of the cooperation for an enterprise. The *value* consequently also encloses the risk of failing respectively the profit contribution for the enterprise. The more comprehensively a cooperation is controlled by contract, the more important it is for an enterprise. A partner can also proceed better in contract injuries.

- The *degree of formalization* finally gives information about the kind and form of the agreements. A smaller formalization points to a smaller importance for the enterprise.

- Finally the criterion *temporal frame* shows that a cooperation put on a long-term basis normally has more cooperative elements than a short-run one. If a cooperation is at short notice, it resembles only a market transaction.

Illustration 2 gives a survey off the criteria of the examined cooperation forms between airports.

Illustration 2: Forms of Cooperations - Results of the Dimension Model

Forms of cooperations	Mutual dependence	Coordination volume	Complexity	Cooperation profit	Value	Degree of formalization	Temporal Frame	Mean number
SOUTH GERMAN AIRPORT ALLIANCE	30	80	70	70	80	50	50	61,43
Airport Union (e.g. ADV - UNION OF GERMAN AIRPORTS)	60	90	90	20	50	10	50	52,86
Airport cooperation Dusseldorf and Gladbach	90	10	80	90	90	30	100	70,00
Airport cooperation Frankfurt and Hahn**	90	60	90	80	100	40	100	80,00
Airport cooperation Munich and Augsburg	80	40	30	70	70	50	100	62,86
Airport cooperation Stuttgart and Baden-Airport	70	30	90	90	90	30	100	71,43
Management contracts (e.g. FRAPORT/Athen-Spata)**	50	10	20	0	80	100	70	47,14
Joint Venture (e.g. PANTARES ALLIANZ)**	80	80	100	50	100	100	70	82,86
Holding (e.g. CENTRAL GERMAN AIRPORT PLC)	50	70	90	100	90	100	90	84,29
Airport System (e.g. Berlin Airports)	90	80	90	100	100	100	100 (20)	94,29
Airport Network (e.g. HOCHTIEF AIRPORT)	70	50	100	50	100	50	100	74,29
Multicorporate Airport Enterprise (e.g. FRAPORT AG)	30	50	80	40	60	50	70	54,29

It becomes clear from the illustration that the cooperative attachment is good in the case of a Joint Venture (e.g. PANTARES ALLIANZ), a holding company (e.g. CENTRAL GERMAN AIRPORT PLC.) and an airport system (e.g. Berlin airports). The mean values of this first group are 80 scale points and more. Noticeable is that the cooperation within an airport system had a better rating in general than the Berlin example, because according to planning in 2004 (this system will be replaced by the new Berlin-Brandenburg-International-Airport) the temporal frame had to be classified with a very small index (20). In airport systems, the temporal frame is usually

to be evaluated very high (value 100) , because for example the title has been denied by the EU up to now.

In the second group there are the majority of the selected cooperations between large airports and their satellite airports as well as the airport network of HOCHTIEF AIRPORT GMBH with still high scale values (mean values between 70 and 80). The cooperation of Frankfurt with Hahn stands out from this group (mean value of 80). In this case, the reasons are mainly the coordination volume (with 60 higher than the others in this group) on account of the airport expansion and accessibility as well as the high weight of cooperation with a neighbouring airport because of the capacity problems in Frankfurt.

The high cooperative attachment of the airport network compared to the other cooperation forms of this group is especially given in the case of complexity and value (with 100 scale points in each case). The criterion *temporal frame* is dominate within this group (100), since the participations and investments can be seen as long-term engagements .

In the third group there are the cooperations which have a mean value of less than 70 scale points. The SOUTH GERMAN AIRPORT ALLIANCE miss a better cooperative attachment only because of small values of criteria of cooperation complexity (70) and of a more detailed formalization of cooperation (50). Cooperation within the SOUTH GERMAN AIRPORT ALLIANCE could be to be intensified in some fields of activities and controlled more comprehensively by contract. In this way the evaluations of the two criteria would improve. The more complex a cooperation is, the larger are its dependence and its temporal frame. The airport cooperation between Muinch and Augsburg is to be seen apart from its affiliation to the SOUTH GERMAN AIRPORT ALLIANCE. Seen in such a way, the dependence of the two partners is by far higher (80) than dependence in the entire alliance (30). The two airports Munich and Augsburg show a very high dependence on account of their proximity and the financial commitment (from the viewpoint of Munich). Coordination (40) and complexity (30), however, are very small compared to the alliance very small since cooperation has only concerned the expansion of Augsburg up to now. This airport cooperation clearly remains behind the above-mentioned ones (Frankfurt/Hahn, Stuttgart/Baden-Airport and Dusseldorf/Gladbach) concerning business functions affected by cooperation.

The examples which have a mean value between 50 and 60 are in the fourth group: GERMAN AIRPORT UNION ADV (52,86) and the multicorporated airport enterprise of FRAPORT AG (54,29). The later is positioned almost on the other side of the continuum hierarchy and nearly out of bounds in the field of cooperation. Management contracts (e.g. between FRAPORT and Athens-Spata) received the lowest dimensioning of all examined cooperation forms. Especially the completely individual cooperation profit (Value: zero) clarify similarity to the barter deal (know-how for payment) and show proximity to the market continuum. The complexity of the management contract was only limited to the flying business, so the evaluation could only turn out very low. An expansion of the complexity can be increased by additional management contracts.

The result of dimensioning and the attempt of a grouping of the analyzed cooperation forms is to be seen in illustration 3.

Ilustration 3: Grouping of selected airport cooperation forms

Grouping of selected airport cooperation forms

Scale values of 0 to 50 Group V	Scale values of 50 to 60 Group IV	Scale values of 60 to 70 Group III	Scale values of 70 to 80 Group II	Scale values of 80 to 100 Group I
Management contract	Airport Union	Airport Alliance	Airport Network	Airport System
	Multicorporated Airport enterprise	Airport cooperations between large airports and their satellite airports		Airport Holding
				Joint Venture

➔ Cooperative attachment ➔

On account of the considerations, experiences from practice and results of dimensioning the cooperative attachment is especially high in the case of Airport Systems, Joint Ventures and Holdings. Especially in airport system good assumptions exists for cooperation.

In particular the important aspect of a possible shift of air traffic between neighboring cooperation partners - even if this can only be realized with great difficulty in reality - is to be put through legally within an Airport System. In the final analysis this aspect becomes the deci-

sive factor for more complex and higher-quality cooperation. However, an Airport System must be approved by the EU, has only got an outlook to success for airports within a common conurbation.

The cooperation forms "Joint Venture" and "Holding" offer similar advantages for a narrow cooperation between airport enterprises as an Airport System with regard to complexity of the affected business fields, value and degree of formalization of the cooperation - except for the aspect "shift of air traffic". Airport Systems and Holdings can be regarded congruently to regard (except for the "shift of air traffic"-aspect), because the European Airport Systems are generally organised in the legal form of a Holding Company.

The examined airport cooperations with investment of a large airport in a satellite airport showed that every situation influences the cooperation in a different way. Great differences are to be found especially at the extent of the coordination and complexity of the cooperation fields. The very low degree of formalization during one-sided investments lets the author presume a controlling majority, so that possibly agreed cooperation contracts are not or hardly not important.

The cooperation form of an Airport Network (e.g. HOCHTIEF AIRPORT GMBH) shows advantages concerning of mutual dependence, complexity, value and temporal frame of cooperation compared to an Airport Alliance (e.g. SOUTH GERMAN AIRPORT ALLIANCE). The clear investment structure and benchmarking by the "center" of the Airport Network HOCHTIEF AIRPORT GMBH is the main reason for the advantages of this form. The selection of members for this Airport Network, the complex benchmarking via all groups and the long temporal frame of the cooperation on account of high investments supports a greater cooperative attachment compared to an Airport Alliance (like the SOUTH GERMAN AIRPORT ALLIANCE).

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MAJOR IMPACTS OF FLEET RENEWAL OVER AIRPORTS LOCATED IN THE MOST IMPORTANT REGION OF BRAZIL

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The present article discusses and analyses the major impacts of the Brazilian carriers fleet renewal regarding Brazilian airport infrastructure in the most important region of the country, the Southeast (SE). A brief historical overview of the country's airline fleet will be presented, demonstrating the need for its renewal (in fact, Brazilian carriers started a major fleet renewal program in the last five years), while analyzing the periods in which a new breed of aircraft was put into service by the major carriers operating in the SE region. The trend of operating the classic regional jets plus the forthcoming entry into service of the "large regional jets" (LRJ, 70-115 seaters) in several point-to-point routes are presented along with the country's carriers' reality of operating these former aircraft in several high-capacity and medium-range routes.

The article will focus on the ability of four of the major Southeast's airports to cope with the fleet modernization, mainly due to the fact that the region studied is the most socioeconomic developed, by far, with the largest demand for air transportation, thus making the impacts much more perceptible for the communities and the airport management involved. With the emergence of these impacts, several new projects and investments are being discussed and pushed forward, despite budgetary constrains being a reality in almost every Brazilian city, even in the SE region.

In view of this, the paper presents how the general planning could be carried out in order to adapt the airports' infrastructures in function of the proposed (and in some cases, necessary) fleet renewal. Ultimately, we will present the present picture and two future scenarios in order to determine the level of service in the existent passenger terminal facilities in the wake of the possible operation of several new aircraft.

Keywords:
Airline fleet planning, Airport planning, Regional development, Regional Jets.

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1. INTRODUCTION

During the 80's and more especially in the late part of the decade, the world began realizing that a new political, economical, social and cultural order was coming to stay. In Latin America it was no different. In Brazil the government began abandoning the regime of indexation of the economy and price regulation. Regarding air transport issues, in November of 1991, seeking to establish a clear set of policies tuned with the liberalization trends being pushed forward by the federal government under then-elected president Fernando Collor de Mello, the Department of Civil Aviation (DAC) lead the organization, implementation and discussions of the V CONAC, the 5th National Conference of Commercial Aviation. Culminating with the liberalization policy (called *flexibilização* in Portuguese, a quasi-total deregulation), in mid 2001 the DAC along the Ministry of Finance published a Ministry Act issuing the full freedom of fares for the domestic market.

In March 2003, Brazil had four major carriers, totaling 251 aircraft in operation: TAM with 103, VARIG with 100, VASP with 26 and GOL with 22 (the later as of April, 2003). The market-share expressed in available-seat kilometers (ASK) for the domestic market in March of 2003 was of 36.43% for VARIG, 31.11% for TAM, 17.64% for Gol, 13.49% for VASP, and near 1,5% for all the other 10-or-so scheduled-service regional airlines.

Since the mid 90s, all Brazilian regional carriers face structural economical problems, mainly because these small regionals cannot reach the most important and lucrative markets between major cities. The city-pairs flown by these regional players do not generate enough traffic to catapult them into a new group of would-be "medium carriers". Thus, nowadays, Brazil has its majors and the small regional players; there are no "medium" size carriers operating in the country. The market-share distribution aforementioned is a clear confirmation of this fact.

2. THE BRAZILIAN DOMESTIC FLEET

With the present division of majors and small regionals, the Brazilian fleet can also be simply divided into three groups:
(1) Medium/large wide-body aircraft operating international routes (VARIG's MD-11s, 777s and 767s, plus TAM's A330s);
(2) medium capacity aircraft for domestic routes (737s in VARIG's, VASP's and Gol's fleets, plus TAM's A320/319 and Fokker F100s), and
(3) a few regional jets (RJs) combined with the assorted turboprop aircraft flown by the regionals.

Due to its importance, this paper will primarily focus on the single-aisle, narrow-body aircraft flown domestically by the major carriers (group 2). This group represents nowadays 66% of the entire Brazilian airline fleet (see Table 1).

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Table 1 – Brazilian Airlines' Fleet Evolution (1990-2002) – Only Scheduled Carriers' Fleets Appropriated

Aircraft / Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
A300-B2/B4	4	3	4	3	3	3	3	3	3	3	3	3	3
A310	–	–	–	–	–	–	–	1	2	2	–	–	–
A319	–	–	–	–	–	–	–	–	–	–	12	6	13
A320	–	–	–	–	–	–	–	–	–	–	6	21	31
A330	–	–	–	–	–	–	–	–	–	2	5	7	9
707-320C	4	3	2	2	2	2	–	–	–	–	–	–	–
727-100/100C	15	14	5	5	5	5	9	9	9	9	7	5	4
727-200/200C	–	–	–	–	–	–	2	4	6	6	2	6	4
737-200	39	43	36	34	36	38	43	38	40	35	35	35	32
737-300	36	54	39	39	38	35	33	40	47	49	46	55	41
737-400	3	7	4	4	4	5	5	6	7	4	1	5	4
737-500	–	–	–	4	4	7	10	14	17	17	19	20	18
737-700	–	–	–	–	–	–	–	–	–	5	5	16	25
737-800	–	–	–	–	–	–	–	–	–	–	–	2	6
747-200/300	8	9	9	11	8	8	6	5	5	5	–	–	–
747-400	–	–	–	–	–	1	1	–	–	–	–	–	–
767-200/300	13	15	16	18	18	19	19	23	23	18	17	17	12
777-200	–	–	–	–	–	–	–	–	–	–	–	–	2
ERJ-145	–	–	–	–	–	–	–	6	11	11	20	18	15
DC-8F	–	3	3	–	–	–	–	–	–	–	–	–	–
DC-10-30/-30F	12	15	12	10	10	10	10	10	10	3	2	3	3
MD-11	–	2	6	9	10	10	16	18	20	21	13	16	14
Fokker F100	2	4	9	14	17	20	28	30	39	39	39	50	48
ATR-42	–	–	–	1	1	3	3	7	10	10	11	14	14
Cessna Caravans	–	–	13	21	27	37	46	45	45	46	45	10	7
EMB-110	45	41	37	31	29	29	44	38	34	34	15	13	8
EMB-120	8	12	12	16	17	22	23	30	27	27	31	29	18
DH Dash-8	–	3	5	5	4	3	–	4	4	2	–	–	–
Fokker F27	19	12	12	8	9	8	8	6	6	6	2	3	3
Fairchild FA22	6	5	5	4	4	3	3	3	3	3	–	–	–
Fokker F50	–	–	2	6	6	16	19	19	15	15	17	10	–
Lockheed Electra II	14	14	12	1	–	–	–	–	–	–	–	–	–
Total Jets	136	173	145	153	155	163	185	207	239	229	232	285	284
Total Trbprops	92	87	98	93	97	121	146	152	144	143	121	79	50
Total	228	260	243	246	252	284	331	359	383	372	353	364	334

Notes: Cessna Caravans includes Grand Caravans — Trbprops = turboprops — EMB-110 = Bandeirante, EMB-120 = Brasília

Source: Department of Civil Aviation Statistical Yearbooks.

2.1. The necessity of fleet-renewal: TAM and VASP

The majority of the aircraft in group 2 are either very old (25+ years in operation) or relatively old (+13 years in operation). Although the age of an aircraft does not directly represent a safety concern, it certainly point towards several disadvantages in the airlines' daily operations, such as a higher fuel consumption, higher rate and cost of maintenance, higher level of noise and gas emissions, lower level of service to passengers (noise, outdated interiors, etc.), plus the smaller number of passengers carried.

This put, any process of fleet renewal of a given airline must constitute a relevant part of the financial projections of the company, in fact being a part within the vital long-range strategic planning done by any carrier. However, in the wake of some particular situations, airlines are practically forced to incur in a fleet renewal or a fleet "replacement" process (not necessarily renewal, but can be combined with). The latter can be exemplified by what has happened with TAM and its Fokker F100s in 2002/2003.

The Dutch-built F100 was acquired in the beginning of the 90s (see Table 1) and was extremely important for TAM's history, not only because it marked the introduction of the jet age in the airline, but that it introduced the jet service in the Rio–São Paulo air bridge (Ponte-aérea/shuttle Rio–São Paulo). This move by TAM forced VARIG, VASP and Transbrasil (then operating as a pool, with VARIG Lockheed Electra turboprop aircraft) not only to discard the Electras from the route, but also to review their strategic position as a pool, which would soon terminate.

Entering service in various major and medium-size cities, the F100 proved to be the workhorse of the airline. Pictured everywhere in TAM's ads and aviation magazines in Brazil, the F100 was associated directly with the airline's new image of modernity. Unfortunately the crash of an aircraft departing from downtown São Paulo/Congonhas (SBSP/CGH) airport in an early morning flight of the Rio–São Paulo air bridge in October 1996, caused the death of all passengers and crew onboard plus several people on the ground. The cause of the crash was determined as beginning in a major malfunction of the starboard engine thrust reverser control devices, prompting it to deploy during the critical take-off run at Congonhas, then worsened by the crew's inability to interpret the on-board computer reactions to minimize the problem. The crew's fight with the on-board computer reactions was a the decisive cause of the crash. The image of the airline was scratched not only due to the horrible accident itself, but also due to the particular flight, which was routinely used by important businessmen, government officials and politicians travelling from São Paulo to Rio.

The following year, when TAM began overcoming the accident in São Paulo, a passenger died when she was literally blown away of another F100 during a flight from São José dos Campos to São Paulo, when a depressurization of the passenger cabin occurred following the detonation of a home-made bomb by a nearby-seated passenger (as reported). Even being a non-aeronautical cause, the accident reactivated the negative public view of the aircraft. At the time these two accident occurred,

TAM stated that it would only return the fleet of F100s if the leasing contracts were not renewed satisfactorily. However, for the unfortunate of the carrier, five year later, in August 2002, on the very same day, two F100 were involved in two emergency landings: one in the Campinas/Viracopos International Airport (SBKP/VKP) and another in a countryside location, both in the state of São Paulo. With the public (mainly business passengers) shifting mostly to VARIG and Gol flights when knowing that a F100 was the assigned aircraft for any given route, TAM decided to anticipate the aircraft replacement. In fact, this replacement was only planned to begin in 2005, but as the serious accidents unfolded and prompted a major negative reaction of the flying public, the company was forced to rethink its strategy. In 2002 the airline decided to return 21 F100 aircraft, out a total of 50.

An airline whose particular situation practically demands an urgent fleet renewal is VASP. The company was once synonymous of new technology when in it brought to Brazil the first Boeing 737-200 Advanced to operate in South America, in 1969, and in 1986 the first 737-300 (then a new model of the 737 family). Regarding the 737-200s, some aircraft are approaching their useful life when analyzed by the number of cycles. Presently, VASP's fleet is composed by three old-version A300s, four 737-300s (mainly operated in the Rio–São Paulo air bridge) and twenty of those veteran 737-200s. Not only due to the nearing end of their operational and economic lives, VASP's 737-200s are noisy Stage 2 aircraft, which should be phased out completely by 2010, as recommended by ICAO.

Complementarily, the airline is aware that the operational limit of the mentioned aircraft will be around the year 2005, since the necessary investments to adapt the aircraft to environmental demands of neighboring airport communities, plus the necessary structural maintenance will turn the operations economically unviable. In reality, the problems associated with the Boeing 737-200s do not affect only VASP, but also VARIG, the other operator in the country.

A major solution for this complex almost-entire-fleet-renewal problem for VASP may come in the form of capturing investments to lease or even acquire brand new models from the Embraer 170/175/190/195 family beginning in 2004 or early 2005 at the latest. This alternative will be briefly explored in a forthcoming section.

2.2. A New Breed of Medium-capacity Single-aisle aircraft

According to analyses conducted by Boeing (2002), the Latin-American market should account for 2100 of the 24.000 jets that the market should acquire in the next 20 years, in a package worth some US$107 billion. This confirms current Brazilian airlines' situation, where almost 65% of the aircraft operating in scheduled passenger transport in the country are in the 100–150 seat range, with an average age of 20 years (DAC, 2002).

In the aircraft market renewal, Airbus Industries announced in 1981 that it would develop an aircraft for short/medium routes, with a 150-seat capacity. After the official launch of the A320 program, in

1984, the first prototype of the aircraft flew in February of 1987, receiving aeronautical certification in February of 1988. The A320 came as a reference in technology, being the first commercial airplane to be completely operated by fly-by-wire, plus the side-stick in replacement of the usual central column stick. With the configuration, the A320 cockpit layout resembled more a F-16 fighter jet than a commercial aircraft. After reprogramming some of the software packages related to the fly-by-wire flight controls, Airbus experienced several successes from the A320 family. In fact, the opportunities of the basic design are such that the manufacturer has built an entire family of twin jets around it: the A321 (a slightly larger aircraft, with a 7-meter fuselage stretch capable of seating 185 passengers in a two-class configuration); the A319 (the slightly smaller derivative of the A320, with a 4-meter fuselage shortening and capable of seating 124 passengers in a two-class layout); and the A318, the smallest member of the family, with a 107-seat configuration in its common internal layout. Clearly, with the launch of the A318 program in the late 90s, the European manufacturer was aiming the "large regional jet" (LRJ) niche market, with aircraft to fill in the need to replace Fokker F100/F70s, 737-200s, and DC-9s/MD-80s worldwide.

Boeing's prompt response to the outgrowth of the A320 family was a far superior successor of the widely known and also greatly successful 737-300/-400/-500 series: the 737-NG (New Generation). The 737-NG can be treated almost as a new family, with its models –600/-700/-800/-900. This family have larger, more aerodynamic wings (25% more area) optimized for higher fuel efficiency, higher speed and higher cruising altitudes, plus more efficient and more powerful CFM56 engines. Moreover, the 737-NGs also have larger fuel capacity, averaging 30% more than the –300/-400/-500 series, paving the way for transcontinental flights and even making it a contender for the lower-end of the ETOPS certification.

As a simplification, one could assume that the –600 model is the natural replacement for the 737-500s and other similar aircraft, while the –700 would replace the –300, the –800 would be a natural substitute for the –400, while the –900 would fit into a "new" market for the family, almost coming as close to a "short 757".

In Brazil, airlines operate with the two manufacturers: TAM operates A319 and A320, respectively 13 and 24 aircraft, while VARIG currently operates 2 Boeing 737-800s and 5 –700s (as January, 2003). Exploring the Southwest-led fleet commonality for low-cost/low-fare carriers, Gol operates an all-Boeing fleet comprising 22 737-NG aircraft (eighteen –700s and four –800s).

2.3. The Regional Jets

The Regional Jet (RJ) phenomenon began in the U.S. as a follow-on to the successes from the turboprops used by the regional and commuter carriers code-sharing with or subcontracted by the majors and nationals. In the beginning used simply as feeder and to link secondary and tertiary cities to the main hubs dominated by the majors, first the turboprops and then the RJs are now under the spotlight with its present darling role of hub bypassing. As mentioned above, the RJs success was

directly derived from the turboprops' own success, being the former much more praised by the flying public for its speed, comfort and sense of safety and modernity. In fact, the RJs were designed to be an efficient yet affordable (in terms of operations) replacement for the turboprops.

Motivated by the success of RJs in the 30–60 seat range and foreseeing a necessity for airplanes to fill the gap between these aircraft and the 737-600/-700 or the A320/319 family, the four main aircraft manufacturers have heavily invested in the "larger regional jet" (LRJ) concept. This entirely new family of aircraft will be in the 70-120-seat range, with an extremely positive market ahead (see forecasts on Table 3). The first attempt came from Bombardier with an outgrowth of its successful CJ700 (a 64-seater), turning it into the CJ900 (90-seater), as already in service with the Mesa Air Group (as of May, 2003).

Table 2 – Regional Jet Order Book by the Two Largest Manufacturers (as of December/2002)

Manufacturer/Aircraft	Delivered	Backlog	Firm orders	Options	Total
Bombardier	775	423	—	—	1198
CRJ100	226	0	—	—	226
CRJ200	463	206	—	—	669
CRJ440	18	57	—	—	75
CRJ700	68	130	—	—	198
CRJ900	0	30	—	—	30
Embraer	623		374	560	1557
ERJ135/140/145/145XR	623	—	256	352	1231
Embraer 170/175/190/195	0	—	118	208	326

Notes: Data as Dec. 31, 2002 – Embraer data does not reflect impact of the Swiss International order renegotiation – Table column key exactly as appears in source – Data does not contemplate an order for 100 170/190s placed by LetBlue in June, 2003.

Source: Bombardier Aerospace and Embraer, via Air Transport World, May/2003.

Table 3 – Regional Jet Deliveries Forecast

Seats per aircraft	2003-2012	2013-2022	2003-2022
30 – 60	1745	1765	3510
61 – 90	1175	1415	2590
91 – 120	1090	1420	2510
Totals	4010	4600	8610

Source: Embraer, via Air Transport World, May/2003.

In the race for the most efficient and most appropriate model to fill the gap cited above, Embraer will probably take a very comfortable position as it is, by now, the sole of the four major

manufacturers (other being Boeing, Airbus and Bombardier) that have developed a totally new design and not an outgrowth of a smaller version (as Bombardier) or, on the contrary, a shortened version of a larger aircraft (such as Boeing with its 737-600 and Airbus with its A318). The Brazilian manufacturer new family is the Embraer 170/175/190/195 (in the 70, 76, 90, 96-108 seat range respectively).

It is important to point that both Boeing and Airbus, with shortened versions of the "not-really-designed-nor-developed-for-regional-jet-service" 737-NGs, Boeing 717 (formerly McDonnell-Douglas MD-85) and A318s, are direct competitors to Embraer's 190/195 models (or vice-versa, as the latter aircraft are still to be produced). It is also important to complement that only the Embraer jets were specifically developed and designed from the drawing boards to be a "large regional jet", this being one of its main advantages over the much heavier competitors' models. However, when bringing to light the relevancy of fleet commonality, an airline may prefer ordering the Airbus A318 or the Boeing 737-600 instead of the Embraer 190/195 simply because it already has other members of the European or the North-American family in the fleet. This is exactly what TAM is considering: the airline has manifested interest in acquiring A318s to replace Fokker F100s. On the other hand, JetBlue, an all-Airbus low-cost/low-fare operator in the U.S., ordered 100 Embraer 170/190 in early June, in a contract worth around US$3 billion.

Complementarily, when considering a major fleet renewal, Embraer with its totally new family of 170/175/190/195s could end up composing the entire fleet of a given small or midsize carrier. VASP's current fleet of veteran 737-200s in their 110-or-so seat configuration is a particular potential candidate for a complete modernization with the new Embraer twin jets. Considering VASP's average load-factor of 50-55%, replacing the old 737s with, for example, a mix of Embraer 170s and 190s would be an extremely interesting solution. In the particular case of VASP, the problem is not with any possible delivery delays of the acquired aircraft (being from any manufacturer); it is the critical financial situation of the carrier that currently blocks any short-range fleet modernization.

Interestingly, several Brazilian aviation professionals say that the new Embraer family is extremely well suited for what they call "first-world operations". The aircraft's embarked avionics and flight characteristics are a pilot's dream, not to mention its airfield performance and reliability in mid-temperatures and cold weather. On the other hand, airlines operating in less-developed or developing countries and without much access to capital, see the new family as extremely costly (US$20+ million the smallest 170) and point that the aircraft would have multiple restrictions if operated in very hot weather and short runways, exactly the cases of almost every non-capital airport in Brazil and in several other developing and less-developed countries. In fact, these aviation professionals argue why Embraer has not yet designed the 170/175/190/195–"Lite" versions, these being a kind of "no-frills" aircraft models of the new family. Time remains to be seen if either Embraer or any other major manufacturer will come any closer to this approach regarding its LRJs.

Table 4 – Profit Improvement – Narrowbody *versus* RJ

Per segment	737-200	50-seat RJ	% change
Revenue (US$)	5.846.23	4,458.90	–24
Expenses (US$)	7,434.88	3,738.00	–50
Operational Income (US$)	(1,588.65)	720.90	n.m.
Margin	–27%	16%	—
Revenue ASM (US$ cents)	0.092	0.167	82
Cost per ASM (US$ cents)	0.117	0.14	20
Yield (US$ cents)	0.144	0.194	35
RPMs (x 1000)	40,669	22,962	–44
ASMs (x 1000)	63,546	26,700	–58
Load factor (%)	64	86	22 pts.
Passengers	76	43	–33

Source: An unidentified U.S.-based major airline, via Air Transport World, May/2003.

3. THE SOUTHEASTERN AIRPORTS FOCUSED

There are approximately 746 public aerodromes registered in Brazil (ROTAER, 2002). The Department of Civil Aviation (DAC), the Brazilian Federal Airport Authority (INFRAERO), states, cities and a few private consortiums are responsible for the management of these public airports. According to Institute of Civil Aviation (IAC) data, 74,456,117 passengers passed through all the 65 airports managed by INFRAERO, being 9,352,856 from international flights and 64,423,933 flying domestically. To demonstrate its importance throughout the system, INFRAERO's airports are responsible for 95% of the total volume of passengers indicated above.

The regional and geographical division of the country is defined by the Brazilian Institute of Geography and Statistics (IBGE), being Brazil presently divided into 5 regions: North, Northeast, Southeast, South and Center-West. Table 5 depicts the territorial distribution and the regions' differences regarding its social-economic power (and consequent political influence).

Table 5 – Geographical Regions of Brazil

Region	Relative area of Brazil (%)	Aerodromes	Gross Internal Product (in US$ millions)	Population
Center-west (CO)	18.87	99	20,700	11,636,728
North (N)	45.25	129	14,289	12,900,704
Northeast (NE)	18.25	171	42,121	47,741,711
South (S)	6.77	133	56,670	25,107,616
Southeast (SE)	10.86	214	187,156	72,412,411
Total	**100**	**746**	**321,390**	**169,799,170**

Sources: ROTAER (April, 2002) and IBGE (via www.ibge.gov.br)

3.1. The choice of the Southeast Region of Brazil – The Importance of Four Airports

Major historical settlements founded by the Portuguese (including turning Rio de Janeiro the country's capital until the 60s, leaving Salvador behind), combined with prosperous mining, agricultural and cultural activities during the 18th and 19th centuries, and more recently the heavy industrialization, were the main reasons for the Southeast to become the most populated and richer region of Brazil. As can be seen in Table 5, population distribution in Brazil is not proportional to the geographical size of each region. This combined resulted in a socioeconomic inequality of the country through a mega-development of the Southeast in contrast with the North, Center-West and Northeast regions. Airport implementation and infrastructure development would not be contrary to this reality: out from the total of 64,423,933 passengers flying domestically, nearly 32% used either one of the four major airports located in the downtown areas of the four capitals of the Southeast region (São Paulo, Rio de Janeiro, Belo Horizonte and Vitória).

3.1.1 Congonhas (downtown) Airport – City of São Paulo, state of São Paulo (SP)

Congonhas (CGH/SBSP) is the second largest airport in passenger volume. It can be said that Congonhas functions almost as a hub for both TAM and Gol, concentrating and distributing traffic originating from of cities of several Brazilian states. Nowadays it is processing approximately 29,000 passengers a day, traveling through 52 different destinations dispersed throughout the country. However, the airport is operated under a series of air side capacity restrictions, while also having serious surface access limitations. This is the direct consequence of the airport being engulfed by the largest and most important city in the country. Back when it was opened to the first flight, in the 30s, Congonhas was no where near the city, its neighbors being far apart farms with its crops and cows. Nowadays, its privileged city-center location is hated by the surrounding communities and beloved by the airlines and thousands of businessmen, politicians and government officials that have to fly routinely to São Paulo.

Congonhas Infrastructure Summary:
- Runways: 17L/35R (1,940 x 49 m) and 17R/35L (1,435 x 49 m), not capable of simultaneous operations.
- Apron area: ~130,000 m^2 — Parking Positions for 26 Aircraft.
- Passenger Terminal operational area: 13,102m^2.

3.1.2 Santos Dumont (downtown) Airport – City of Rio de Janeiro, state of Rio de Janeiro (RJ)

Rio de Janeiro/Santos Dumont airport (SDU/SBRJ) is the fifth busiest airport in Brazil in terms of passengers. The main connection to/from SDU is to São Paulo/Congonhas through the Rio–São Paulo shuttle (*ponte-aérea*), the main route in the country. The other most important links to/from SDU are to Belo Horizonte/Pampulha (PLU/SBBH) also in the SE region and to Brasília (BSB/SBBR), the country's capital.

In the beginning of the 90's the airport experienced a major modernization of its operations: the introduction of jet service by TAM (Fokker F100s) and by the VARIG/VASP/Transbrasil pool right after (737-300s). Before these aircraft entered service, the Ponte-aérea had been operating the Lockheed Electra II turboprops (in VARIG colors) for 18 years. In just a few months, fourteen Electras were replaced by ten 737-300s, combining a substantial increase in capacity (from the 90 seats in the Electra to the 132 seats in the 737s) with a slight reduction in flight time (the flight became 7-10 minutes faster, in average).

Santos Dumont Infrastructure Summary:
- Runways: 02R/20L (1,323 x 42 m) and 02L/20R (1,260 x 30 m), not capable of simultaneous operations.
- Apron area: ~65,000 m^2 — Parking Positions for 15 Aircraft.
- Passenger Terminal operating area: 4,952 m^2.

3.1.3 Pampulha (downtown) Airport – City of Belo Horizonte, state of Minas Gerais (MG)

The airport began its activities as a technical stop in the flights of the Military Airmail, in 1933, in the then-called "Linha do São Francisco" ("San Francisco Route", named after the river São Francisco that extends from the Northeast region all the way through the state of Minas Gerais) linking Rio de Janeiro (then capital of Brazil) to Fortaleza. In 1937 this technical stop in Belo Horizonte was transformed into a routinely-flown link to Rio de Janeiro, at the time operating the twin-engine Lockheed 10E Electra I, with a two-men crew and the capacity for six passengers.

Beginning in the early 70s, already under INFRAERO management, Pampulha airport (PLU/SBBH) grew steadily with the development of air transport in the country and particularly in the Southeaster region. Soon, the already community-engulfed airport could not satisfactory support the increasing demand and the need for new services, mainly international flights. In view of this, the Ministry of Aeronautics (through INFRAERO) decided to finance and buitd a new airport, to be located far away from growing Belo Horizonte. The Confins/Tancredo Neves International Airport (CNF/SBCF) was opened in January 1984, being considered at the time one of the most modern facilities in Brazil. A few months after opening, the new international airport registered about 75% of the movement of aircrafts and 95% of the passengers in the Belo Horizonte area.

For the desperation of the surrounding communities and for INFRAERO itself, Pampulha started to regain one flight after the other, starting from 1986 with the creation of the direct flights among the downtowns of the cities, linking the downtown airports of Rio, São Paulo, Belo Horizonte and Brasilia (the then-called VDCs or "Vôos Diretos ao Centro", standing for "Direct Flight to the Center"). The picture got even worse with the multiplication of jet services during the 90s, where Pampulha completely outpaced Confins in passenger and aircraft served. This reflected the consequences of the majority of businessmen, politicians and government officials traveling to/from Belo Horizonte preferring to fly to/from downtown Pampulha than to/from distant Confins

International. Today, the later airport is even called a "white elephant", being one of the most underused sites in the country, despite being a top-level international facility.

> Pampulha Infrastructure Summary:
> - Runway: 13/31 (2,540 x 45 m).
> - Apron area: 36,456 m^2 — Parking Positions for 8 Aircraft.
> - Passenger Terminal operational area: 4,500 m^2.

3.1.4 Vitória International Airport – City of Vitória , state of Espírito Santo (ES)

According to INFRAERO data, there are presently 74 aircraft daily in the airport, with eight airlines operating almost a million passengers per year. The number of passengers transported in January of 2002 was the largest of the airport's history to date: 104,781 passengers, a number 20% higher if compared with January 2001.

Vitória International (VIX/SBVT) registers one of the highest rates of growth in the country, with 12% per year, well above the national average of 8%. With the recent discovering of a great number of highly potential oil fields near the coast of the state of Espírito Santo, the opportunities for an even higher growth of the state's economy may push forward a major modernization of the airport. In fact, INFRAERO has already a draft project to review the airport master plan, where a second runway would be added along a new passenger terminal building and new cargo facilities.

> Vitória International Infrastructure Summary:
> - Runway: 05/23 (1,750 x 45 m).
> - Apron area: 24,360 m^2 — Parking Positions for 6 Aircraft.
> - Passenger Terminal operational area: 3,294 m^2.

3.2. Major Links to/from the Four Airports

In Brazil, the number of frequencies and the schedule of each given flight are defined for DAC, by the scheduled airlines, under bulletins called *Hotran* (for "Horário de Transporte", or Schedule of Transports). The capacity of any given flight (or route, when all *Hotrans* of that route are summed up) vary according to the number of frequencies, the size and configuration of the aircraft used by the airline(s) and specified in the *Hotran* document.

According to the manufacturers (Boeing, 2002), airlines (should) acquire airplanes to fly specific routes in view of their market and demand forecast studies. Therefore, Tables 6 through 9 will present the destinations flown by the scheduled airlines in their routes to/from each of the four depicted airports, pointing the percentage of each equipment type used in a given airport for a week.

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Table 6 – Destinations to/from Congonhas Airport (CGH), in 2002

City/Destination	No. of flights per week	737-200	737-300	737-500	737-700	737-800	A319	A320	F100	ERJ145	ATR 42
Araraquara	18										18
Araçatuba	12								12		
Araxá	6									6	
Belém	28	7				7		7	7		
Belo Horizonte	196		11	67	33			73	2	10	
Brasília	223	14	15	32	41	7		88	26		
Bauru	18								18		
Campo Grande	53		7	6	13		13	7	7		
Criciúma	16								16		
Corumbá	7								7		
Curitiba	232		7	49	33			114	29		
Caxias do Sul	41			17					24		
Cuiabá	52		7	6	13		6	14	6		
Pres. Prudente	23										23
Manaus	21				7			14			
Florianópolis	65		14	11	7	14		6	13		
Fortaleza	41				20		7	14			
Rio de Janeiro (GIG)	80				22	14		21	23		
Goiânia	72	7			38			7	20		
Ilhéus	34			14				20			
Santana do Paraíso	10									10	
Imperatriz	6								6		
Juiz de Fora	19										19
João Pessoa	7							7			
Joinville	47			31					16		
Campinas	13						7		6		
Londrina	51							19	7	25	
Marabá	7								7		
Marília	23										23
Maceió	1		1								
Macapá	21	7				7		7			
Navegante	55			29	7			12	7		
Santo Ângelo	6									6	
Natal	7		7								
Porto Alegre	185		7	54	26	7		48	31	12	
Passo Fundo	6									6	
Porto Seguro	14			7				6	1		
Recife	42		7		14	7		14			
Rio de Janeiro (SDU)	593		286	6	75		202			24	
Ribeirão Preto	65							20	16	29	
São Luis	6								6		
São José do Rio Preto	28							14	7		7
Salvador	115		1	23	28	14	35	7	7		
Comandatuba	2						1	1			
Uberlândia	69								39	30	
Uberaba	29									11	18
Varginha	12										12
Vitória	61		7	13	12			6	23		
Canoas	6										6
Chapada Diamantina	2			2							
Mucuri	3										3
Ji-Paraná	6								6		
Total flights (per week)	2755	35	377	367	389	77	271	546	395	169	129
Equipment market share (%)	100%	1%	14%	13%	14%	3%	10%	20%	14%	6%	5%

Source: SGTC – Sistema de Gerenciamento de Torres de Controle (April 2002)

Table 7 – Destinations to/from Santos Dumont Airport (SDU), in 2002

City/Destination	No. of flights per week	737-200	737-300	737-500	737-700	737-800	A319	A320	F100	ERJ145	ATR 42
Belém	14				7		7				
Pampulha	136		7	56	19				52	2	
Brasília	136		7	6	61		46		10	6	
Campo Grande	5		5								
Curitiba	45		7		27					11	
Cuiabá	5		5								
Florianópolis	2		2								
Campinas	63		7		34				11	11	
Maringá	6				6						
Macapá	7						7				
Porto Alegre	15		2	6						7	
Petrolina	6									6	
Recife	7				7						
Ribeirão Preto	5								5		
São José dos Campos	13			6						7	
São Paulo	588		286	6	74		202			20	
Uberlândia	6									6	
Vitória	96		7	30	20				25	14	
Total flights (per week)	1155	—	335	110	255	—	262	—	103	90	—
Equipment market share (%)	100%	—	28%	10%	22%	—	23%	—	9%	8%	—

Source: SGTC – Sistema de Gerenciamento de Torres de Controle (April 2002)

Table 8 – Destinations to/from Pampulha Airport (PLU), in 2002

City/Destination	No. of flights per week	737-200	737-300	737-500	737-700	737-800	A319	A320	F100	ERJ145	ATR 42
Brasília	84	7		25	12			14	16	5	5
Curitiba	13								13		
Fortaleza	7				7						
São Paulo (GRU)	5										5
Gov. Valadares	15										15
Santana do Paraíso	30									10	20
Campinas	39				14				13	12	
Montes Claros	16									6	10
Natal	7	7									
Poços de Caldas	5										5
Palmas	5									5	
Porto Seguro	7								7		
Recife	14	7			7						
Rio de Janeiro (SDU)	136		7	55	19				53	2	
São Paulo (CGH)	200		12	61	41			75	1	10	
Salvador	27	7		7					7	6	
Uberlândia	16								11		5
Vitória	84	7			13				12	47	5
Araguaiana	5									5	
Total flights (per week)	715	35	19	148	113	—	—	89	133	108	70
Equipment market share (%)	100%	5%	3%	20%	16%	—	—	12%	19%	15%	10%

Source: SGTC – Sistema de Gerenciamento de Torres de Controle (April 2002)

Table 9 – Destinations to/from Vitória International Airport (VIX), in 2002

City/Destination	No. of flights per week	737-200	737-300	737-500	737-700	737-800	A319	A320	F100	ERJ145	ATR 42
Belo Horizonte	84	7			13				12	47	5
Brasília	27	7			7			·	13		
Boundaries	5	5									
Criciúma	5								5		
Curitiba	7				7						
Fortaleza	7								7		
Rio of Janeiro (GIG)	28	7							11		10
São Paulo (GRU)	18	7							11		
Gov. Valadares	5										5
Joinville	5								5		
Campinas	18				7				11		
Maringá	6				6						
Montes Claros	6									6	
Maceió	7	7									
Porto Seguro	1								1		
Recife	7	7									
Rio de Janeiro (SDU)	96			29	27				25	15	
Ribeirão Preto	5	5									
São Paulo (CGH)	69		14	13	13			6	23		
Salvador	24	14							4	6	
Petrolina	7								7		
Total flights (per week)	437	66	14	42	80	—	—	6	135	74	20
Equipment market share (%)	100%	15%	3%	10%	18%	—	—	1%	31%	17%	5%

Source: SGTC – Sistema de Gerenciamento de Torres de Controle (April 2002)

4. THE IMPACT ON THE INFRASTRUCTURE

4.1 Options for Direct Aircraft Replacement

According with the links listed in the previous tables, there are ten different types of aircraft operating in the domestic scheduled market in the four Southeast airports depicted. Among these ten types, 50% can be labeled as "new aircraft" (less than 10 years of service), while the other remaining 50% can be treated for simplicity as "old aircraft" (10+ years of service). In view of this, after interviewing several government and airline officials, and academics involved in air transport issues, ideas of what possible future replacements could be managed by the Brazilian carriers and their current operational fleets emerged. These opinions are depicted on Table 10:

Table 10 – Possible Replacement for Several Aircraft in Use by Major Brazilian Carriers (2002)

Aircraft to be replaced (*)	Possible Replacement Aircraft (*)	Difference in seating capacity	Motivation and/or Justification
737-200 (95)	737-600 (110) **	+ 15%	Aims in maintaining the overall dimensions (wingspan and length) in order to simplify airport planning (same aircraft planning group), while permitting the fleet modernization. Individual airlines should study fleet commonality and associated technical aspects in order to determine what type/family/manufacturer it would ultimately chose for the envisioned fleet modernization.
737-200 (95)	A318 (107)	+ 13%	Aims in maintaining the overall dimensions (wingspan and length) in order to simplify airport planning (same aircraft planning group), while permitting the fleet modernization. Individual airlines should study fleet commonality and associated technical aspects in order to determine what type/family/manufacturer it would ultimately chose for the envisioned fleet modernization.
737-200 (95)	ERJ 190-100 (98)	+ 3%	Aims in maintaining the overall dimensions (wingspan and length) in order to simplify airport planning (same aircraft planning group), while permitting the fleet modernization. Individual airlines should study fleet commonality and associated technical aspects in order to determine what type/family/manufacturer it would ultimately chose for the envisioned fleet modernization.
737-500 (110)	737-700 (126) **	+ 14%	
737-500 (110)	A319 (124)	+ 13%	
737-300 (128)	737-800 (162) **	+ 26%	
737-300 (128)	A320 (150)	+ 17%	
Fokker F100 (108)	A318 (107)	– 1%	TAM is the only operator of that aircraft (F100) in Brazil, and because of fleet standardization, it could most probably opt to transition to the smallest aircraft of the A320 family.
ATR-42 (48)	ERJ-145 (50)	+ 4%	Several routes now been operated by turboprops could transition to jets, given that the airports depicted herein are capable of operating the new aircraft. Being Embraer a Brazilian manufacturer and as its aircraft are already flying everywhere in the country, a natural choice would be replacing these turboprops with ERJs (financial and or other capital-related issues not addressed here).

Notes:

(*) Number of passengers with typical configuration, according to manufacturer's data.

(**) For simplification and comparative results, the aircraft with the largest capacity was chosen.

Source: Table elaborated by the authors, after consultations with Brazilian aviation experts..

4.2 The Apron

The apron dimensions are directly related to the dimensions of the aircraft that will be operated in that facility. In short, lengths, wingspans, wheel-bases and ground envelopes will determine the separation distances among the aircraft themselves, the turning and taxi tracks, plus the separation of the parked aircraft to the passenger and cargo terminals, just to mention a few examples.

For planning proposes, aircrafts are classified in groups by physical (dimensions) and operational characteristics. This classification distributes several aircraft inside a same group. For example, aircraft inside of a certain wingspan strip they are grouped in a single letter. The standards for aircraft group classification was set forth by ICAO and they were published in Annex 14, the official ICAO recommendation for Airport Planning (Standards for Configuration and Operations of Aerodromes).

This paper assumes, for simplification of the airport planning studies, that the future number, the position and the group of aircraft that operate in a given airport will not be different from the present day, only the types/variants/models of aircraft will be a matter of substitution (see Tables 10 and 11). Therefore the planning groups presently in use by the airport authority in Brazil to overlook the airport master plan will be maintained to make possible a better analysis regarding operation of the aircraft mentioned herein. In view of this, Table 11 presents possible new configurations of the four listed airport aprons as the operating airlines opt to invest in a fleet renewal process.

Table 11 – Aircraft on the Apron in 2001 and the new Configuration Proposed (%)

		737 200	737 300	737 500	737 600	737 700	737 800	A318	A319	A320	F100	ERJ 145	ATR 42
Santos Dumont (RJ)	2001	-	28	10	-	22	-	-	23	-	9	8	-
	Proposed	-	-	-	-	32	28	9	23	-	-	8	-
Vitória (ES)	2001	15	3	10	-	18	-	-	-	1	31	17	5
	Proposed	-	-	-	15	28	3	31	-	1	-	22	-
Pampulha (BH)	2001	5	3	20	-	16	-	-	-	12	19	15	10
	Proposed	-	-	-	5	36	3	19	-	12	-	25	-
Congonhas (SP)	2001	1	14	13	-	14	3	-	10	20	14	6	5
	Proposed	-	-	-	1	27	17	14	10	20	-	11	-

Source: Table elaborated by the authors based on the airports' master plan data.

The aircraft compatibility – because of being from the planning group – makes possible a smoother transition regarding the impacts on the apron. However in some cases, the operation of the new equipment can generate significant effects in the planning parameters, mainly in safety and security.

To reach more specific results of that impact on the apron, a meticulous analysis of the physical characteristics of the equipments (particular aircraft-type dimensions) is required.

4.3. Passenger Terminals

To make the capacity of a passenger terminal compatible with demand is one of the main roles of the airport management. The capacity of an airport should be able to grow in response to the most effective and flexible form of management. Unfortunately, airport expansion limitations are

enormous in several cases and very difficult to be implemented in its desired, original overall concept. Within this complex situation lies the necessity of planning far ahead, in the long-range mode (it is not uncommon to plan for 20-30 years, but yet very difficult to predict mainly the technological advances that could be incorporated in this period). One of these difficulties is the necessity of airlines renewing their fleets with modern, sometimes an "unthinkable" aircraft 15-20 years in the past (the Airbus A380 and the now-shelved Boeing Sonic Cruiser are examples of this kind of aircraft, just as the 747 and the Concorde were in the mid-to-late 60s).

As in other areas of the airport, the passenger terminal can be related to a level of service that it provides. According to IATA (International Air Transport Association), the level of service is considered as a limit of values or an evaluation of the ability of supplying the demand combining amount and quality of the services, for consequence respecting the desired (predicted/planned) comfort and convenience of the terminal for the passengers (present and future demands, as forecasted in appropriate studies for that matter). Therefore a great difficulty exists in establishing a quantifiable relationship between available space and level of service.

To allow a comparison in large-scale, between the several systems and sub-systems of an airport, while still reflecting the dynamic nature of passenger demand (seasonal peaks, for example), IATA established a measure of variation in the level of service of a passenger terminal, ranging from "A" to "F" (Table 12). IATA recommends level "C" as the minimum required to offer a satisfatory-to-good level of service, with of reasonable implementation/operation costs.

Table 12 – Levels of Service for Planning Purposes according to IATA (square meters per passenger)

Terminal Area Level of Service	A	B	C	D	E	F
Check-in area	1.8	1.6	1.4	1.2	1.0	UNACCEPTABLE
Circulation area	2.7	2.3	1.9	1.5	1.0	
Departure gates/lounges	1.4	1.2	1.0	0.8	0.6	
Baggage claim areas (arrival)	2.0	1.8	1.6	1.4	1.2	
Primary Recommended Totals (m²/pax)	7.9	6.9	5.9	4.9	3.8	

Legend (levels of service):

A = Excellent. Free flow and excellent comfort level

B = High. Flow stable, few delays and high comfort level.

C = Good. Stable flow, acceptable delays and good comfort level.

D = Appropriate. Flows unstable, small delays and appropriate comfort level.

E = Inadequate. Unstable flows, unacceptable delays and inadequate comfort level.

F = Unacceptable. Crossed flows, unacceptable delays and unacceptable comfort level.

Source: IATA, Airport Development Reference Manual.

In the present study, in order to develop a brief analysis of the passenger terminals' situation regarding a possible comprehensive fleet renewal by Brazilian major airlines, and its possible impacts in the four Southeast airports herein highlighted, three scenarios were elaborated based on Department of Civil Aviation official statistical data:

- **Scenario 1** – The load factor of the aircraft involved will be the average of 2001 (base year) and the fleet will continue the same (in other words: 2001 demand; 2001 fleet/capacity);

- **Scenario 2** – The load factor of the aircraft involved will be the average of 2001 (base year) and the fleet will be renewed (2001 demand; new fleet, as proposed)

- **Scenario 3** – The load factor of the aircraft involved will increase (targeted year in the future = 2006) and the fleet will be renewed, as proposed (new demand [increased]; new fleet).

(Note: According to DAC data, traffic in Brazil has grown 62.2% from 1997-2001; for simplicity, this growth was extrapolated to the 2001-2006 period in this study. This extrapolation, here depicted in Scenario 3, is more conservative than the original DAC data for its "most favorable" scenario).

The first step for the application of the proposed Scenarios will be the determination of the number of passengers that will be carried by the new proposed aircraft. These numbers were calculated based on the weekly use of each equipment (see Tables 6 to 9), thus generating more data. With the numbers of the possible future volumes of passengers, Scenarios 1 through 3 were generated for each of the four airports herein listed:

4.3.1 São Paulo/Congonhas Airport

Table 13-A – Weekly participation of aircraft and total of proportional passengers used per equipment – CONGONHAS
(Considering the apron in its full capacity of 26 aircraft)

Equipment	% Apron Today (Table 11)	Actual Pax	% Apron Proposed (Table 11)	Proposed Pax
737-200	1	25	—	—
737-300	14	466	—	—
737-500	13	372	—	—
737-600	—	—	1	29
737-700	14	459	27	885
737-800	3	126	17	716
A318	—	—	14	389
A319	10	322	10	322
A320	20	780	20	780
F100	14	393	—	—
ERJ-145	6	78	11	143
ATR-42	5	62	—	—
Total	100	3083	100	3264

Notes:

% Apron Today = Apron percent usage by an aircraft in a period of one week. (base = 2001).

% Apron Proposed = Proposed apron percent usage by an aircraft in a period of one week.

Actual Pax = A proportional number of passengers that now uses certain equipment for a weekly use (proportion between apron use and the full capacity of the aircraft).

Proposed Pax = A proportional number of passengers that will use certain equipment for a weekly use (proportion between apron use and the full capacity of the aircraft).

Table 13-B – Proposed Scenarios for Congonhas/CGH

	Scenario 1	Scenario 2	Scenario 3
Average load-factor (per equipment)	63.57% (*)	63.57%	100% (**)
Passengers carried	1960	2075	3264
Average no. of passengers per aircraft	75	80	126
Square meters per passenger	6.69	6.31	4.01
Level of service	C	C	F

Notes:

(*) Data obtained from the DAC Statistical Yearbook.

(**) Load-factor in base-year 2001 with the increment of 62.2% (increase of demand without considering increasing the number of frequencies).

Square meters per passenger = Actual passenger terminal operational area divided by total passengers calculated.

Level of service "F" denotes urgent need for passenger terminal expansion.

4.3.2 Santos Dumont Airport/Rio de Janeiro downtown

Table 14-A – Weekly participation of aircraft and total of proportional passengers used per equipment – SANTOS DUMONT
(Considering the apron in its full capacity of 15 aircraft)

Equipment	% Apron Today (Table 11)	Actual Pax	% Apron Proposed (Table 11)	Proposed Pax
737-200	—	—	—	—
737-300	28	538	—	—
737-500	10	165	—	—
737-600	—	—	—	—
737-700	22	416	32	605
737-800	—	—	28	680
A318	—	—	9	144
A319	23	428	23	428
A320	—	—	—	—
F100	9	146	—	—
ERJ 145	8	60	8	60
ATR 42	—	—	—	—
Total	100	1752	100	1917

Notes: See Table 13-A.

Table 14-B – Proposed Scenarios for Santos Dumont/SDU

	Scenario 1	Scenario 2	Scenario 3
Average load-factor (per equipment)	57.14% (*)	57.14%	92.67% (**)
Passengers carried	1001	1096	1770
Average no. of passengers per aircraft	67	73	118
Square meters per passenger	4.95	4.52	2.79
Level of service	D	E	F

Notes:

(*) Data obtained from the DAC Statistical Yearbook.

(**) Load-factor in base-year 2001 with the increment of 62.2% (increase of demand without considering increasing the number of frequencies).

Square meters per passenger = Actual passenger terminal operational area divided by total passengers calculated.

Level of services "E" and "F" denotes urgent need for passenger terminal expansion.

4.3.3 Pampulha Airport/Belo Horizonte downtown

Table 15-A – Weekly participation of aircraft and total of proportional passengers used per equipment – PAMPULHA
(Considering the apron in its full capacity of 8 aircraft)

Equipment	% Apron Today (Table 11)	Actual Pax	% Apron Proposed (Table 11)	Proposed Pax
737-200	5	38	—	—
737-300	3	31	—	—
737-500	20	176	—	—
737-600	—	—	5	44
737-700	16	161	36	363
737-800	—	—	3	39
A318	—	—	19	163
A319	—	—	—	—
A320	12	144	12	144
F100	19	164	—	—
ERJ 145	15	60	25	100
ATR 42	10	38	—	—
Total	100	813	100	852

Notes: See Table 13-A.

Table 15-B – Proposed Scenarios for Pampulha/PLU

	Scenario 1	Scenario 2	Scenario 3
Average load-factor (per equipment)	45.72% (*)	45.72%	74.16% (**)
Passengers carried	371	390	632
Average no. of passengers per aircraft	46	49	79
Square meters per passenger	6.30	6.00	3.70
Level of service	C	C	F

Notes:

(*) Data obtained from the DAC Statistical Yearbook.

(**) Load-factor in base-year 2001 with the increment of 62.2% (increase of demand without considering increasing the number of frequencies).

Square meters per passenger = Actual passenger terminal operational area divided by total passengers calculated.

Level of services "E" and "F" denotes urgent need for passenger terminal expansion.

4.3.4 Vitória International Airport

Table 16-A – Weekly participation of aircraft and total of proportional passengers used per equipment – VITÓRIA
(Considering the apron in its full capacity of 6 aircraft)

Equipment	% Apron Today (Table 11)	Actual Pax	% Apron Proposed (Table 11)	Proposed Pax
737-200	15	86	—	—
737-300	3	23	—	—
737-500	10	66	—	—
737-600	—	—	15	99
737-700	18	136	28	212
737-800	—	—	3	29
A318	—	—	31	199
A319	—	—	—	—
A320	1	9	1	9
F100	31	201	—	—
ERJ 145	17	51	22	66
ATR 42	5	14	—	—
Total	100	586	100	614

Notes: See Table 13-A.

Table 16-B – Proposed Scenarios for Vitória/VIX

	Scenario 1	Scenario 2	Scenario 3
Average load-factor (per equipment)	47.54% (*)	47.54%	77.12% (**)
Passengers carried	279	292	473
Average no. of passengers per aircraft	46	49	79
Square meters per passenger	10.09	9.63	5.94
Level of service	A	A	C

Notes:

(*) Data obtained from the DAC Statistical Yearbook.

(**) Load-factor in base-year 2001 with the increment of 62.2% (increase of demand without considering increasing the number of frequencies).

Square meters per passenger = Actual passenger terminal operational area divided by total passengers calculated.

5. CONCLUSIONS

Any study involving fleet renewal is already a complex task. This paper has presented, in a simplified approach, some of the possible impacts of a comprehensive fleet renewal conducted by scheduled carriers operating in the Southeastern states over the current infrastructure of four of the major airports in the region (São Paulo/Congonhas, Rio de Janeiro/Santos Dumont, Belo Horizonte/Pampulha and Vitória). As the great majority of the aircraft operated in these airports are medium-sized twin-jets, the study opted to focus primarily these aircraft and their possible replacements.

For this, the study identified the existence of ten different types of aircraft operating in the scheduled domestic market from the four depicted airports. For simplicity, these aircraft were herein separated into two distinct groups: an "old" group with 737-200s, 737-300/-400/-500s, Fokker F100s and ATR-42s; and a "new" group comprising 737-NGs (-700/-800), A319, A320 and Embraer ERJ-145.

The simple fleet renewal pictured in this paper was guided by the principles of fleet commonality, the maintaining of approximately the same overall dimensions, and a possible fleet modernization (in the case of the turboprops). Due to the diversity of the physical and operational characteristics of the aircraft involved, only the relationships among the replaced and replacement aircraft, the apron and the passenger terminal were listed. In fact, due to the maintaining of the overall dimensions (replacement aircraft in the same airport design/planning group of the replaced aircraft), the possible impacts of the fleet renewal proposed over the apron were practically discarded in the present study. However, it must be pointed out that a detailed study should be carried out in order to evaluate existing ramp equipment configuration and compatibility in relation to the proposed replacement aircraft.

In order to permit a broad comparison among the four airports, the level of service indexes recommended by IATA were used to evaluate possible future capacity constrains and passenger comfort levels in the respective passenger terminals. For this, three scenarios were built for each airport, based on the last official data (2001) for passenger volumes. These scenarios give a brief overview of what could happen with the level of service in the four airports' passenger terminals if a +60% increase in demand is confirmed, a comprehensive fleet renewal is carried out, but no terminal expansions are planned. These possible impacts can be summarized:

- São Paulo/Congonhas (CGH/SBSP) is operating on the level of service lower limit (IATA level "C"), and it will maintain the same level with a fleet renewal, despite a small reduction in the relation of square meters/passenger (as shown in Scenario 2). However for a mid-term scenario (Scenario 3), Congonhas' terminal would become unacceptable, as it would reach IATA's level of service "F".

- Rio de Janeiro/Santos Dumont Airport (SDU/SBRJ) is already operating below the desired minimum ("C") as it obtained a level "D" for the present demand. With a major fleet renewal it would get even worse, falling to level "E" (shown in Scenario 2). For the mid-term future (Scenario3), Santos Dumont's passenger terminal would match Congonhas as well, being unacceptable in IATA's indexes (would rock bottom at level "F").

- Belo Horizonte/Pampulha Airport (PLU/SBBH) has also shown that it has already reached its operational limit (level "C" in the present passenger demand data). This level will be maintained with a major fleet renewal, but, as Congonhas, with a small reduction in the square meters/passenger relation (as pointed by Scenario 2). However, just as Congonhas and Santos Dumont, Pampulha will also reach level "F" if the forecasted increase in demand materializes complementarily with the major fleet renewal (Scenario 3).

- Vitória Airport (VIX/SBVT) is a totally different case from the other three airports. It is presently operating under the highest level of service ("A"), and will continue with the introduction of the proposed replacement fleet (as depicted in Scenario 2). Interestingly, if compared with the other airports, Vitória will maintain a level "C" for its passenger terminal even in the event of maximizing demand in the mid-term (Scenario 3).

It is important to observe that the majority of equipment located in an airport or in use by an airport is dimensioned proportionally to the 5, 10 or 20-year forecasted volume of passengers that are processed by the facility. Thus, if capacity and/or level of service problems already do exist in a given passenger terminal, it will certainly impact negatively in several other facilities in the airport site. This put, the present study has demonstrated the relevancy of considering fleet renewal options as an important variable for present and future airport planning in Brazil.

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Effects of the Deregulation on the Concentration of the Brazilian Air Transportation Industry

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Abstract

This paper addresses the effects of the deregulation of the Brazilian air transportation industry in terms of the concentration of the market. We will show some metrics that are commonly used to study the concentration of the industry. This paper uses the Herfindhal-Hirschman Index. This index tends to zero in the competitive scenario, with a large number of small firms, and to one in case of a monopolistic scenario. The paper analyses the dynamics of the concentration of the Brazilian domestic air transportation market, in order to evaluate the effects of deregulation. We conclude that the Brazilian market presents oligopoly characteristics and aspects in its current structure that maintain the market concentrated in spite of the Deregulation measures adopted by the aeronautical authority.

Keywords: Herfindhal-Hirschman Index , concentration, Deregulation

1. Introduction

Sales or production concentration is related to the industry market distribution among companies according to their size. For the air passenger transportation industry the product that is being offered by the air transportation companies is the seat of an aircraft. This

production plays a relevant part in the industry market structure since it should determine the behavior and development of the air transportation company.

The economical theory suggests that structural characteristics of an industry sway its behavior, as well as its prices, costs, profits and inventive activities in the market. This paper is about one of the main dimensions of the air transportation industry, the production concentration. It assumes that the number and size distribution of companies influence the expectations related to the behavior of the competitors. For example, in an industry scenario with a small number of companies, each one playing an important role in a market that is not coming to any growth, the increase in sales of one company will mean failure for the others. The companies soon discover why they lost market share and probably react trying to get back their participation. A company usually cannot take aggressive initiative in a market without consideration of the probable reaction of the competitors. Besides, the number of companies and their participation in the market can influence the possibility of collusions. Collusions will surely be successful if the number of companies in the industry is small.

So, the reader can notice that the concentration level of an industry can determine the dynamics of the playing companies and, indirectly, the industry own development. In a detailed analysis, Industrial Concentration is understood as a process of growth of the market power of the larger companies on the economical activity. The concentration level is a measurement that expresses the structure of the industry.

One of the first studies in Brazil about concentration of an air transportation industry is the paper developed by Espírito Santo (2000). It contains an analysis about the quality of the national industry concentration and identifies reasons that may increase the industry concentration. In the author's own words:

"... in 1998, VASP and Transbrasil started a code-share agreement in several domestic connections. Although it was finished in some months, this was the beginning of new domestic alliances. Practicing the code-share, the companies can commercialize their flights together, as if they were one company. This way, the partner companies can cut

down on the expenses related to giving information about flights, can come to the reduction of frequency in the constant connections in the agreement – and this way, cut down on the offering of seats and schedule – and can reduce the passenger's service level and the straight competition. This competition, from contestant companies, can become seriously involved."

In Oliveira's study (2001) we're able to notice the importance of studying the concentration in the air transportation market:

"... Although there has been much criticism upon what we call Behavior-Structure-Paradigm – that consists in the relation between the concentration level in a market (its structure) and the power of the companies (behavior structure) – the writings on air transportation have become even more emphatic in pointing that the predominant strategies all over the world have been emphasized. Besides, the evidences of domestic alliances creations have been sufficiently concrete to assure that the market power in the industry has increased more and more. That way, we've come to the conclusion that the control of the concentration levels and of market power in sections like the air transportation has become one of the most important attributes of the authorities, looking forward to promoting their own good."

Our next section will discuss the possible ways to measure the concentration, as well as we intend to justify the index chosen to calculate the concentration level in the Brazilian Air Transportation Industry.

2. Concentration measurements

There are several alternative indexes to measure concentration. At first we've got to know however what are the desirable properties required from a concentration measurement. Hall and Tideman (1967) suggested the following desirable properties:

(I) a concentration index should have only one dimension,

(II) the measurement shouldn't depend on the size of the industry, but it should consist in a measurement worked out among the group of companies present in the industry, that is, each company contribution answers for its participation in the industry or in the economy,

(III) the concentration measure must increase if the participation of a company in the market increase upon another – a smaller one. It means that the principle of transfers must be used, if necessary. The <u>principle of transfers</u> will be defined here as the process in which the efficient companies get part in the market because of the inefficient ones

(IV) if all the companies are divided in similar parts, the concentration measurement must decrease accordingly. For example, if two companies are divided in two equal parts, then the concentration will have to decrease by half

(V) the concentration measurement must be decreasing when related to the number of companies

(VI) a concentration measurement should be between zero and one

A more understandable series of properties is determined by Hannah and Kay (1977):

(I) the adhesion of new companies of some relevant size must reduce concentration

(II) unions must increase concentration

(III) costumers changing at random for a specific brand must decrease concentration

(IV) if P_i represents the participation of a new company, when it becomes progressively smaller, the effect on the concentration index must also be like that

(V) random factors in the growth of companies should increase concentration

Next, some of the most commonly used concentration measures will be shown, as well as the theory about them.

2.1. Concentration index (C)

It's the most frequently used measure. It measures the participation of the n biggest companies, that is:

4

$$C = \sum_{i=1}^{n} P_i \qquad (1)$$

P_i - participation of company i in the market

n – number of companies

All the companies that are included in the measurement are equally treated; in other words, they receive net weight 1. The concentration index only provides limited information about the distribution of companies through number and size. Picture 1 shows the concentration of two markets in the Brazilian air transportation industry, the connections:

Altamira (SBHT) – Belém (SBBE),

and Belo Horizonte (Pampulha – SBBH) – Brasília (SBBR).
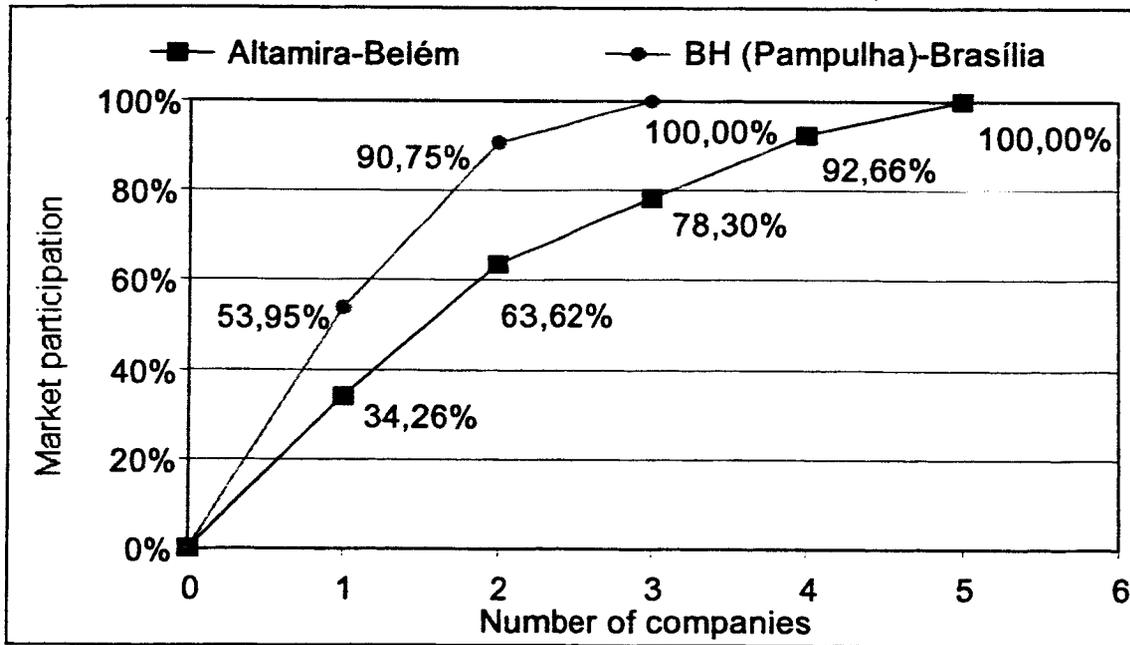
Picture 1

The information on picture 1 can be used to find the minimum number of companies that represents some specific participation of market. In SBHT – SBBE, two companies

represent 63,62% of the market, while in SBBH – SBBR this number goes up to 90,75%. It's possible to see through picture 1 that the lines do not touch each other, in any place. This fact implies that the organization of the connections will not be affected by the choice of *n* companies. In cases like that, for any number of chosen companies, the SBBH – SBBR connection will always be the most concentrated among the two analyzed.

Picture 2 shows the concentration at two other connections in the Brazilian national air transportation market:
Rio de Janeiro (Galeão) – Salvador
and São Paulo (Guarulhos) – Curitiba.
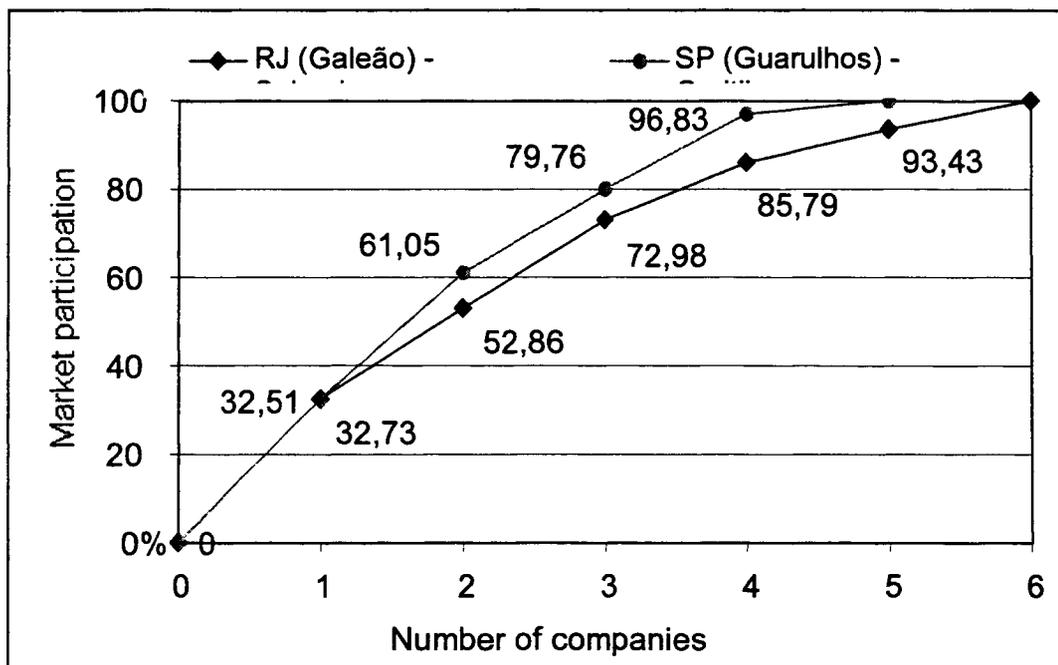
Picture 2

On picture 2, the concentration index for two companies shows that SP (Guarulhos) – Curitiba market is more concentrated than RJ (Galeão) – Salvador one. But for comparisons, the concentration index considering only one company is inverted, that means, RJ (Galeão) – Salvador connection is more concentrated.

Literally, this concentration index is, many times, presented in a different way:

$$CR_m = \frac{\sum_{i=1}^{m} X_i}{\sum_{i=1}^{n} X_i} = \sum_{i=1}^{m} P_i \qquad (2)$$

X_i – represents what the interest is

P_i - indicates the part of market of the company on the total amount

n – total number of companies in the market

m – represents the biggest companies in the market, and m is smaller than n, or similar to it

Generally, the values used are CR4 (or C12), and these measurements can be defined as a variable number of concentration that indicates the percentage of the correspondent industry related to the four (or twelve) biggest companies in the industry. Actually, what's considered is the participation of the biggest companies, that means, it's the result of concentrating the m biggest companies in a market with n companies.

According to Feijo et $al.$ (2001), the economical literature suggests concentration zones to classify the markets. These indicators can be seen next:

Grid 1 – Concentration zones according to C and CRM indexes

Concentration zones	Definitions
Not concentrated at all	Markets in which the biggest companies have a participation of 25% or less
A little concentrated	Markets in which the participation of the biggest companies results between 25% and 50%

Concentrated	Those with a market participation varying from 50% to 75%
Very concentrated	The market participation of the biggest companies is 75% or more

Source: Feijo et al. (2001)

2.2. Herfindhal-Hirschman Index (HHI)

It can be defined as:

$$HHI_i = \sum_{i=1}^{n} P_i^2 \quad (3)$$

P_i – participation of the company

n - total number of companies in the industry

The highest value an index can reach equals to 1, and this is possible when there's one only company in the market. The minimum value (in which the companies are all the same size) depends on the number of companies. That way, when $n = 100$, the minimum index is 0.01. For example, if two air companies have, each one, a percentage of 50% of market participation, the Herfindhal-Hirschman index is $0.50^2 + 0.50^2 = $ ½.The index gets near to zero, in a competitive case, with a great number of small companies, and it is equals to one in a monopoly case – it means, companies generally present great power of market in this situation, and that can bring loss to the costumers. We can find, in some cases, HHI values calculated in absolute numbers. For example, the same last situation, two companies with 50% of market participation were considered. Their HHI value would be 5000 points ($50^2 + 50^2 = 5000$). The square measure means that the smaller companies contribute less than proportionally for the index value. A simple example can illustrate the different orders varying according to the measurements:

Grid 2 – Comparison between concentration index (C) and Herfindhal-Hirschman index (HHI)

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	Industry A		Industry B	
n	P_i (%)	P_i^2	P_i (%)	P_i^2
1	50	0,25	80	0,64
2	40	0,16	10	0,01
3	10	0,01	10	0,01
	100	0,42	100	0,66

Both scenarios bring the concentration index (C) of two companies presented in 90%, but the Herfindhal-Hirschman index (HHI) is of 0.41 for Industry A and 0.65 for Industry B. The concentration index (C) does not consider the relative size of the two biggest companies, while the Herfindhal-Hirschman index (HHI) does. HHI satisfies all the desirable conditions identified by Hall Tideman and Hannah-Kay and mentioned before in this paper. Besides, this index has received increasing theoretical support. Carlton and Perloff (1998) assure that there is a relationship between HHI and the Market Power. The market structure can be classified according to the HHI value. Some books propose the following classification:

Grid 3: Market structure classified according to the Herfindhal-Hirschman index

Structure	HHI	Price competition intensity
Perfect competition	Usually less than 0.2	Hard
Monopolized competition	Usually less than 0.2	Depends on how much different the products are
Oligopoly	From 0.2 to 0.6	Depends on the competition among the companies
Monopoly	More than 0.6	Soft, unless there's the possibility of new competitors

2.2.1. Comments

As we could see through the studies and comparisons, there are many writings in The United States that verify the concentration effects on fees among cities served by air lines, once the industry was deregulated. Carlton and Perloff (1998) quote some papers where

they noticed that the fees are higher where the concentration is also higher. These papers are from Call and Keeler (1985), Bailey, Graham and Kaplan (1985) and Graham, Kaplan and Sibley (1983). And they could also notice there's a relevant statistics effect of concentration upon development, even though it's got a modest size. The researches concluded by Borenstein (1992), Brueckner, Dye and Spiller (1992), Evans and Kessides (1993) discussed the concentration on the American market. In these writings, the most used measure was HHI, and that's because it respects all the desirable properties and is easy to be handled.

The United States Justice Department provides the following concentration zones to measure the concentration level of an industry:

Grid 4: Placing zones

HHI	Classification
0.00 – 0.10	Low concentration
0.10 – 0.18	Controlled concentration
0.18 – 1.00	High concentration

According to these zones, the American department uses the verified changes on the HHI to decide if a company fusion can be allowed or not. The agency analyses the situation carefully: if the intended transaction happens in a controlled concentration market, and provokes more than 0.01 of addition on the HHI, or 0.005 in high concentration markets, the agency will understand that this transaction probably wants to create, or emphasize, the market power (or make its functioning easier). That way, the proposal goes through a hard analysis to identify the possible impacts on the competition and the needy solutions to approve the fusion.

In Brazil the usage of concentration measurements (HHI) in the fusion of two beer companies: Brahma and Antártica, could be notice

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This paper uses the Herfindhal-Hirschman Index (HHI) to analyze the concentration in the Brazilian National Air Transportation Industry.

3. Concentration analysis: Brazilian National Air Transportation Industry – from 1982 to 2000

This section aims to verify the possible impacts on the concentration due to the deregulation rules the Brazilian government has adopted for the last few years. To do so, we'll show the procedures used to calculate the Herfindhal-Hirschman Index (HHI), and its development throughout the years chosen for the present study.

We use the concept of *Aggregated* and *Disaggregated Concentration*. The *Aggregated Concentration* considers the HHI index calculated over the market participation of the commercial groups of air companies, not over the individual participations of each company. For example, VARIG Organization is formed by four companies: VARIG, Rio-Sul, Nordeste (since 1995) and Cruzeiro (1991/92). The *Aggregated Concentration* considers the participation of the four companies as one commercial group. The *Disaggregated Concentration* on the other hand determines the HHI index for each company using the individual participation of each company *i*, as if it were an independent company.

To calculate HHI, a database was created, with the yearly market share of each company from 1982 to 2000. The primary source of information was the Annual Statistics Report of the Brazilian Air Transportation Industry, a yearly publication of the Civil Aviation Department. The market participation of the national companies was measured by means of the offered seat.kilometers.

Having the market participation of each company, HHI was calculated through formula 3 (*Aggregated* and *Disaggregated Concentration*). For a better and clearer understanding picture 3 shows the progress of concentration levels in the national market throughout the years, measured in HHI.
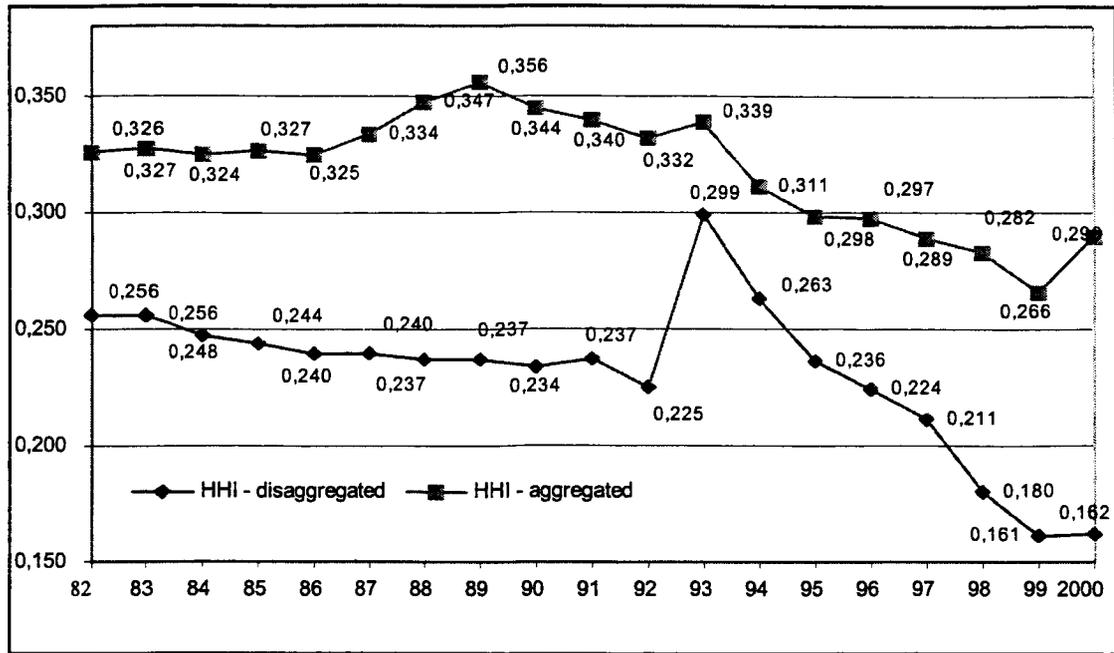
Picture 3

The reader can notice in picture 3 that from 1982 to 1991 the aggregated concentration kept high levels – as considered by the economical theory. According to grid 3, we can classify the market structure of that time as an oligopoly. And we know that in this market, a few companies are responsible for the biggest part or for the total of the production. In some markets, some of or all companies get profits in long terms, once there are obstacles to the entrance of new companies in the market (that makes more difficult the joining of new companies). In this specific case, there was an oligopoly controlled by the government until 1991. The fees were controlled by the public power, aiming to cover costs and expenses of minimum wages. The policies in use from 1982 to 1991 were in great part the responsible for the high concentration levels of the national industry. The controlled competition was adopted because the authorities believed that the free competition among companies could make them grow weak, technically, operationally and financially.

Other reasons that helped the achievement of high market concentration were:

(I) entrance obstacle: the joining of a new company in the market needed government authorization, and what could be noticed was that, in general, it didn't allow the joining,

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aiming to "avoid great competition". From 1982 to 1991, there weren't new companies' joining the industry, but in 1986. One thing that contributed to this situation was that there were great economics of scale (Silva e Lopes, 1994). So, if one company wanted to join the market, it would have to produce in smaller scale and get higher costs than the established ones. At this time, the Department of Civil Aviation divided the country in five areas, and chose, for each one of these regions, one local company to monopolize routes between countryside and capitals. One needy aspect for a competitive market to exist is the possibility of companies freely coming and going in the market, and that wasn't exactly happening.

According to several authors, the control air companies have upon computer reservation systems is considered the main obstacle when new companies want to join the market. In Brazil, till the end of the 80's, each one of the national companies had its own reservation system. From 1990 on computer reservation systems started to be more diffused. These systems were widely known, and the Brazilian companies had to change their old and poor systems for one of the most known systems throughout the world – not to harm their internal sales (Nishime, 1996). That's why there isn't reservation systems controlled by national companies anymore nowadays; almost all of them use systems controlled by foreign companies. In late 80's and early 90's, if a new company wanted to join the market, it would find difficulties in having its flights presented in similar conditions of those already in the market. And if by chance, it chose a new system, it would have to make it popular – it was an expensive procedure and yet, it would face the opposition of the ones already in place. If it chose to join one of the most known systems in Brazil, it would have to share places with a big company, what, for sure, would put the beginner in disadvantage when using or presenting flight information. Yet, a beginner would have to face the preference for the companies with higher market share.

Hall and Tidman (1967) assured that the concentration must decrease when related to the number of companies, and that way, the obstacles that didn't permit new companies to get in the market contributed to high concentration in the national air transportation market, from 1982 to 1991.

(II) <u>route and frequencies</u>: the regulated market did not allow companies to compete on fees; so, one alternative instrument that could have been used was the increase in routes and frequencies. But these possibilities were also controlled by the Department of Civil Aviation, the institution practically imposed its progress factors. These limits controlled any kind of competition among air companies, leading to stronger companies (the big ones) and stronger groups formed by companies with objectives in common. The increase in concentration happened because the big companies had their participation in the market higher at the expense of the smaller ones.

Another reason that led the market to a high concentration was VARIG group. It presented a superior growth when related to the others. At that time the group was formed by two national companies (Cruzeiro and VARIG) and two other regional companies (Rio-Sul and Nordeste). Besides, TAM started to get its group together, with Brasil Central from 1986 on.

The reader must have come to the conclusion that the government ruled the concentration of the companies from 1982 to 1991. This instrument can be useful in promoting the economic efficiency of the companies, however, we have to consider its effects on the passenger, yet. This high level of concentration in the industry brought losses to the users, as we can see: high fees, decrease in routes and frequencies and smaller number of served cities – everything because there was no competition in the area.

But from 1992 on, this situation started to change, and there was an opening process controlled by the air transportation section in the Department of Civil Aviation. Once again, if we observe picture 3, we'll see that the aggregated concentration of the industry started to diminish in 1990. This decrease was interrupted in 1993, when Cruzeiro left VARIG group. Therefore, the new rules set for the air transportation were efficient, when considering the effect on the concentration.

This way, we'll display our analysis to check if this low concentration level was enough to bring any new competition to the market. First of all, it's possible to see that the number of companies in the market grew – more air companies in the market means less concentration measurement. As it's known, the concentration is decreasing when related to the number of companies acting in the market. Again the policy in place played important role in the process of making the number of companies in the market grow. In 1992, the government banished some obstacles for the regional companies. Article of number 688/GM5/92 set the so called Special Air Lines (connecting some downtown airports: Congonhas, Santos Dumont and Pampulha among themselves and with Brasília's airport). Then, these regional companies started to have more possibilities of competing, and counting on the advantage of being in the central airports, with the greatest volume routes of traffic. Another important factor was that they could start being used from any region.

In the end of 1997 and beginning of 1998, the institution sent two important management writings to emphasize the competition among the companies of air transportation. 986/DGAC provided the companies with fees and discounts of 65% on the steady value, and 05/GM05, that freed "any Brazilian air company to use the special lines". These two new happenings provoked immediate impacts on the section's competition, once in March / 1998 a real war of fees was started.

The direct reflexes of this deregulation can be summarized in two main aspects:

(I) air fares reduction and
(II) multi air fares instroduction

As the Department of Civil Aviation stopped controlling the concentration of the national company, the air transportation companies started to set different strategies to act in the market. That way, some national companies began to use more efficient instruments in management. The so called *Yield Management* techniques, already in use in many countries all over the world (Oliveira, 2000). Using these techniques, even only in part, can be considered a good indicator that the market presents a greater sense of competition if

compared to the years when the concentration level was controlled by the government. So, the industry opening led the national companies to set new goals to their organizations, and to search ways for a better participation in the market.

Even with this market opening, there still are several obstacles blocking new companies to join Brazilian market. These obstacles make the industry even more concentrated, and there's loss if competing. We have:

(I) *access to a basic infrastructure*: a company that would like to start air service would face a big difficulty: get space at the airports, because almost all of them are totally busy with the companies that already exists. The situation gets even harder if the "candidate company" tries to enter the market using the airports with more traffic – where it's more difficult to get space, not only related to physical conditions of the airport, but also to to the limitations of frequency that the new company could have. There's also the fact that the noble timetables can be totally filled, and only the periods of less movement would rest. The space given to each company is determined by Infraero, the company that manages the most important airports in the country, according to their respective market participation. On the last few years, problems of traffic started to appear in airports, mainly in Congonhas (SP). They blocked the taking off and landing of the companies, and due to that, any company, new or not, that doesn't operate in Congonhas will face obstacles – physical dependences and windows, taking off in noble timetables totally busy. Most of the main Brazilian airports on the other hand do not hava any serious problem of space for new eventual companies. But this does happen due to the efforts of Infraero, that appears to take the appropriate actions to maintain the capacity of these main airports. As we see, the situation is comfortable, however, in the future Infraero's decisions related to airport spaces will be seen as if they were a market institution. So, we must include the decisions that refer to the management of airports on the political acting of the government, related to the air transportation market (mainly subjects about spaces in the airports).

(II) *market strategies for the companies that already exist*: some market strategies used by air companies can make things even more difficult if a new company wants to join the

market. We can emphasize the existence of programs that try to create loyalty to a certain company or group through prizes.

In 1996, VASP, VARIG and TAM started to such programs, stimulating passengers to be loyal to the airline. This has made passengers to elect to use the service of one company – at least the ones who use it frequently – and it makes more difficult for smaller companies to participate in the market (they have less participation in routes determined in the market as a group).

Júnior *et al.* (1998) conclude that a negative fact coming from the deregulation was that it facilitated the acquisition of smaller companies by the large national or regional companies. Therefore, although the concentration level decreased because of the measures adopted, the market today could be a lot less concentrated if the authority had used instruments to control the concentration. We can check it through picture 3, where we have the concentration measured without thinking about group influence (disaggregated concentration). We come to the conclusion that the authority made a mistake in this aspect, because it allowed comercial group formation. This situation in the future can provoke a decrease in competition in this section, once as time goes by, there's a greater chance for these groups to use their market power.

4. Final considerations

The Brazilian market, even after the deregulation measures adopted, keeps several characteristics of an oligopoly. The opening process of the Brazilian industry is recent, and that's why it's going through some adjustments according to the new policies in the market. Some corrections and adjustments on number of companies working on the deeper routes of the Brazilian market probably will come to happen according to the great number of companies offering services for any of these routes. That emphasizes one fact: the industry has tended to concentrate, it means, the Brazilian market has followed trends from other countries with similar markets, and that makes the number of air companies offering the air transportation service small. So, a few companies have relevant parts of the domestic market, leading to a control of market not desired, when it comes to competition. The

sections that control the air transportation market could take some initiatives, so that the market would be more competitive, like trying to avoid abuses when using reservation systems, coordinate decisions about routes and spaces in the airports, check and control alliances and agreements that can result in excessive control of routes and frequencies of an airport on an only group's hand. Just to control fees of an activity does not mean a decrease in prices because of competition, it's also necessary a proper environment to exist competition. Following trends noticed in other countries, the Brazilian market has a small number of companies, what means a concentrated market. Even in markets like the American one, totally free, the number of companies is proportionally small, and there's also the case of one only company operating in an airport.

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The impact of total liberalization of domestic air transport on the social welfare and on the dynamic of competition: comparison between United States and the European Union

By Karim. Zbidi[1]

Abstract

Since the $1^{st} of April 1997$ date of the implementation of the third package of the liberalization, air transport within the european Union has become totally liberalized. In the United States the deregulation of domestic air traffic was earlier and faster since it took place in October 1978 after the adoption of the only act of deregulation. This paper, in its first part, deals with the liberalization of the industry of air traffic in the european union. After a comparison with US system based on market demand, fare policy and network restrictions, we present our descriptif results coming from treatments on the OAG data. These results present several aspects such as the evolution of the competitive structure of the intra-european routes, the level of airport dominance and the growth of hub structure.

The second part of the paper presents models of entry in the airline industry. As profitability of route flown explains correctly decisions taken by airlines to serve or not a route, the paper focuses on the specification and the estimation of the determinants of city pair profitability in the european union. Treatments done on the OAG data show a rapid development of leasing space agreement(partial and total) and code sharing practices between 1995 and 2000 in Europe that's why we differentiate first between the two type of competitive strategy of entry(direct

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entry and leasing space agreement) and second between the competitive strategy of entry and the alliance strategy of code sharing. So the estimation of model will be able to answer the question if the european air transport market is contestable and in case not to see if the decision of entry is more directed by the level of airport dominance (as in the domestic United States market)or essentially by the competitive structure of the routes. We try to explain the nature of entry(direct leasing or code sharing) by the different levels of these two determinants.

The deregulation of domestic air transport in the united states took part considerably in the reduction of plane tickets real fares. a fall which involved a social welfare profit estimated on average at 4.04 dollars of 1977 per passenger (over the period 1978-1983) according to S.A.Morrisson and C.Winston [13]. Fares variation was done in such a way that tariffs suggested become more adequate with costs supported by the airlines to offer their service on different markets. The proliferation of tariffs is another consequence of the deregulation which is explained by the policy of price discrimination practised by companies to discriminate between passengers according to their willingness to pay.

The adoption of hub and spokes networks is another principal consequence of the deregulation. The number of real competitors (inverse of herfindhal index) have been reduced on a national scale giving place to a greater concentration but this didn't prevent the intensification of competition on the route level. This new structure of network also led to a stronger concentration of the airports which became dominated by one or two airlines.

The travellers saw the quality of certain aspects of service worsening. The flights duration and the average load factor increased so it becomes more difficult to find a place in time preferred flights. However, these losses have been widely compensated by the improvement of other quality aspects of service, in particular the increase in flights frequencies and the reduction of interconnected flights (connected flight between two different airline)(M.Gaudry et R.Mayes[15]).

1 The experiment of the liberalization of the air transport in Europe

1.1 Comparison with domestic air transport in the United States

Compared to american domestic air transport market, the intra-european market presents different characteristics. In the demand side, the competing potential of the other means of transport is more significant in Europe than in the United States. Indeed, although the population of Europe is more significant than that of the United States (380 million against 280 million in 2001), Europe presents

a smaller geographical space . This difference of surface results on an average distance per flight less significant into Europe than with the United states. In 2000 the average distance traversed by the intra-european flights was estimated (balanced by the annual frequency of the flights) at 869 km whereas with the United states it was established to 1665 km (Air Transport Association ATA). This relatively short stage length explains the stronger competition of the other means of transport in Europe. Moreover, the technological projection of high-speed trains allows a more significant competition of railroads transport in Europe.

The aggregate size of the european airlines is less significant than that of the american air companies. In 2000, the joined production of all the american airlines rose to 1114 billion passenger kilometers whereas the european airlines (members of the AEA) generated 613 billion passenger kilometers during the current of the same year. Moreover the traffic of the european companies is much more directed towards the international. Indeed, only 26.6% of the total passenger traffic of the American airlines in 2000 (measured as a passenger kilometers) (corresponds to 8% of passengers)was international whereas more than 91.1% of the european airlines traffic was international (55% of passengers). This international orientation is partially explained by the small size of countries composing Europe, but if Europe is seen as a one geographical entity, the percentage of the international traffic (towards country except european geographical space) remains relatively high with 77.5% (45% of the passengers) (Source ATA and AEA).

The charter traffic (low-cost included), much more present in Europe than in the United States, is an additional side of divergence. Indeed in 2000 25% (50% of the passengers) of the european airlines traffic was served in charter mode, a mode which transports a broad part of the leisure traffic at a very competing tariffs. This same figure does not exceed the 1.3% (0.8% passengers) for the american airlines. All these characteristics of the air transport industry in Europe imply that the demand side benefit from liberalization will be less significant in Europe than from deregulation in the United States.

In the side of pricing policy, the european process of liberalization, in its first package, offer airlines the possibility to propose reductions until 55% less expensive than the coach fare. The second package had more flexibility by authorizing reductions until 70% and by weakening the constraint of double approval, henceforth a tariff will be implemented if the two respective governments do not notify

their refusal at the end of 30 days after the fare demand . The third package came into effect in January 1993 and introduced the complete liberalization of the tariffs from January 1996. Although these measurements of liberalization allowed a fare's drop of 20% on average, the yield in Europe remained relatively high. Indeed in 2000 the yield from american airlines domestic traffic was only of 0.09$ per passenger kilometers transported (PKT) whereas the european airlines ones related to the intra-european traffic was established at 0.37$. The average distance, relatively more important, in the United States can explain a part of this yield's difference but this effect remains partial. In fact, following the deregulation, the yield of the domestic traffic in the United States dropped much more quickly than the one of intra-european traffic following the liberalization process.

One of the most popular explanation of the relatively high yields in Europe is that the european airlines would profit from a significant market power which rise from the practices of collusive pricing strategy. Indeed, the system of bilateral agreements which existed between the states members of the european union is suspected of having implemented then reinforced such collusive practices between airlines.

However measurements which were made concerning market power in the industry of air transport in Europe do not plead for a cooperative pricing system. Indeed the estimate of the standard conjectural variations model(see Good, Roller and R.c sickles [3]) leads to a parameter of behavior which suggests a pricing in conformity with cournot model. It is true that the studies made on Europe are based on aggregate data and thus a heterogeneous behavior of the airlines with respect to different routes remains possible.

Brander and Zhang [17] studied the question of market power in the industry of the american airlines and they concluded that the data are much more compatible with the model of cournot competition than the Bertrand one or the model of collusive behavior. Another branch of the literature suggests the existence of a significant market power in the industry of air transport in the United States. Hurdle [16] and Whinston and Collins[23] studied the assumption of contestability of air transport market in the United States. They found that the market isn't contestable and that on some routes, airlines are able to increase excessively their profit . This joins the remarks made by Borenstein [2] and Berry[20][21] which specify that the airlines are able to increase their yields on a given route through

a strong presence on the two extreme airports and the domination of a hub.

Neven, Roller and Zhang[5] conclude the market power in the air transport european market is not appreciably more significant relative to the market of domestic transport in the United States. Moreover the available aggregate data suggests that the european airlines do not exert any collusive practice of pricing. Indeed they estimate that the profit margins observed are coherent with a non cooperative nash equilibrium.

Given these results, it appears obvious that it is necessary to seek elsewhere for the explanations of the relative rise of the yield in Europe. There were several explanations presented in the literature. All these explanations put forward a relatively high unit cost in Europe. This high unit cost can be explained either by a higher prices of factors or productive inefficiencies.

Neven, Roller and Zhang[5] estimated a model that endogenizes costs and the dynamics of competition on the market of transport in Europe. They concluded in addition to the fact that the prices observed are not in conformity with a colluding practices, that the relative rise of prices of the factors cannot explain the level of unit cost of the airline in Europe and that the most reasonable explanation would be the technical lack of efficiency.

Indeed when the firms are technically inefficient, the weak profit margins can be associated high unit costs that the firms can allow themselves because of the lack of competing pressure. In this case the fares will be high because the costs are so and the margin fare-unit cost will be small. Encaoua [9] and Good[4]were leaning on the question of productive efficiency of the european airlines. They highlighted that, compared with the american airlines, the european airlines are of 50% to 70% less productive.

1.2   Descriptive results of intra-european air transport

The liberalization process of the airline industry was set up with the aim of ending with the situation of monopoly from which profits several airlines, and of dropping fares through the intensification of the level of competition within the european union.

In what will follow we will present our results from treatments on OAG data. These data were available for the years 1995, 1999 and 2000 i.e for the period of partial

liberalization (1995) and that of total liberalization (after 1997). These results are articulated around three axes: the competing structure within the intra-european routes, growth of hub structure and the level of domination of european airports. It's important to mention that all results concern only intra-european flights for which traffic is totally liberalized. This is done to find the most credible comparison with domestic air traffic in the united states.

Concerning the domestic air traffic industry in the united states, JAN K.Brueckner and Pablo T.Spiller [14] mentioned that after an initial decline, industry concentration has increased at the national level over the post-deregulation period. They also remarque that despite this rising national concentration of the industry, competition in the average city-pair market has grown over the period.

	1995	1999	2000	%(1995/2000)
Q1	146	161	164	12.3
Q2	152	172	169	11.2
Q3	153	167	175	14.3
Q4	157	169	187	19.1
Annual	181	197	210	16.0

TAB. 1 – *The Evolution of airline's number operating within the european union*

The evolution of the number of airlines operating regular routes within european union gives an overview of liberalization incidences. Indeed, as shown in table 1 this number rose on average by 16% between 1995 and 2000 with differences over quarters. This rising number of operating airlines doesn't necessarily mean a concentration's decline in the european union because the level of concentration depends on the distribution of market shares between airlines companies.

Table2 show the level of concentration within the european union based on ASK (Available seat kilometers) shares.

The level of concentration doesn't appear to be sensitive to seasonality phenomenon, so the level of concentration is globally the same for high and low season. The main information shown in table 2 is a marked decrease in market concentration between 1995 and 2000. Indeed, the real number of competitors increased by more than 41% from 18 to 26. Thus the real number of airlines increased much more rapidly than the number of airline operating which implies an intensification of competition in

	Real airline's number[1]	
High season(Q2-Q3)	1995	18.40
	1999	22.04
	2000	26.04
Low season(Q4+Q1)	1995	18.29
	1999	21.93
	2000	25.39

1: Defined as the inverse of Herfindhal index

TAB. 2 – *Level of traffic's concentration within the European union*

the city-pair market level.

So, the intra-european concentration decreased at the aggregate and city-pair levels between 1995 and 2000 allowing more route competition.

It is interesting to see how this competition growth had affected flight distribution between different airports. To do this, we proceeded by classifying intra-european airport into four categories: large hub, medium hub, small hub and nonhub. Thus an individual airport falls into one of four hub classifications based on that airport's percentage of total ASK at intra-european airports. Those airports treating 1 percent or more of the total are classified as large hubs, airports treating between 0.25 and 0.99 of the total are classified as medium hubs, airports treating between 0.05 and 0.24 percent of the total are classified as small hubs, and those treating less than 0.05 percent of the total are classified as nonhubs. For example, in 2000, there were 29 large hubs, 41 medium hubs, 68 small hubs and 131 nonhubs.

Larges Hubs	1995	29
	1999	30
	2000	29
Moyens hubs	1995	37
	1999	38
	2000	41

TAB. 3 – *Hubs number for domestic traffic within european union*

Table ?? insists on the fact that the number of large hubs remained stable between

1995 and 2000 whereas the one of medium hubs grew from 37 to 41. This means that the companies were developing their traffic around the medium hubs probably because of the saturation of large hubs.

		Large Hub	Medium Hub	Small Hub	Nonhub
	Large Hub	31.8	22.0	16.2	15.4
1995	Medium Hub		2.1	3.8	2.5
	Small Hub			2.9	2.4
	Non Hub				1.1

Nb. total scheduled flights[1]: 2821

		Large Hub	Medium Hub	Small Hub	Nonhub
	Large Hub	29.2	25.3	16.2	14.2
1999	Medium Hub		2.6	4.7	2.3
	Small Hub			2.5	2.2
	Non Hub				0.9

Nb. total scheduled flights: 3997

		Large Hub	Medium Hub	Small Hub	Nonhub
	Large Hub	28.7	27.1	15.2	13.3
2000	Medium Hub		2.9	5.0	1.9
	Small Hub			2.7	2.6
	Non Hub				0.7

Nb. total scheduled flights: 4249

1: thousands

TAB. 4 – *Distribution of scheduled flights per pairs of classified hubs within the European union (expressed as a percentage)*

This observation is widely consolidated by results from table4 on the distribution of scheduled flights within the European union. Indeed, this table shows that more than 80% of total flights, come from or go to a large hub which emphasis the preponderance of hub structure networks in serving intra-european traffic demand. The number of scheduled flights grew rapidly between 1995 and 2000, more than 50% in five years. This growth had been mainly absorbed by flows of traffic between large and medium hubs. Indeed the share of flights between large hubs decreased between 1995 and 1999 whereas the one between large and medium hubs increased

by 5 points. Airlines appear to prefer developing regional hubs where slots are much more easily obtained and the delays are less significant.

	1995	1999	2000
FRANKFURT	100	114	112
PARIS(C.DEGAULLE)	89	102	104
AMSTERDAM	89	93	96
BRUSSELS	88	80	86
PARIS(ORLY)	87	64	65
MUNICH(INTL)	84	102	107
DUESSELDORF	75	101	98
MADRID	75	75	77
LONDON(GATWICK)	73	79	81
BARCELONA	73	78	80
LONDON(HEATHROW)	73	65	61
HAMBURG	71	78	82
COPENHAGEN(INTL)	71	69	69
NICE	71	68	60
ATHENS	67	62	63
ROME(FIUMICINO)	67	72	73
STOCKHOLM(ARLANDA)	67	78	81
MILAN (LINATE)	62	68	71
STUTTGART(ECHTERDINGEN)	59	66	74
DUBLIN	57	56	61
LONDON(STANSTED)	41	62	81

TAB. 5 – *Number of cities within the european union connected to large hubs*

Table 5 and 6 show the evolution of the number of endpoints served by large and medium hubs within the european union. We note that globally the number of city connected for large hubs doesn't grow as faster as the number of endpoints connected to medium hubs. This can be explained by the fact that for large hubs the jump in number of connected cities have been already done before 1995 whereas medium hubs are now in full extension.

	1995	1999	2000
NUREMBERG	32	47	52
BIRMINGHAM	34	35	43
ALICANTE	25	33	41
EDINBURGH	27	36	39
NAPLES(INTL)	22	36	39
FARO	20	34	38
PORTO	28	28	38
BOLOGNA	22	36	35
MARSEILLE	32	33	34
TOULOUSE	29	39	33
BREMEN	23	29	32
TURIN	22	23	27
BILBAO	21	23	25
LYON(ST. EXUPERY)	53	54	52

TAB. 6 – *Number of cities within the european union connected to medium hubs*

The different type of operations are defined as follows:

1. Leased space flight: A flight where the operating airline leases some seats/space to one or more other airlines and all participants to such an agreement sell their seats/space on that flight under their own designator(s)

2. Joint operation flight a flight on which more than one airline operates one or more of its legs.

3. Code shared flight: A flight where the operating airline allows seats/space to be sold by one or more than one airline and all participants to such an agreement sell their seats/space on that flight under their own Flight Designator. Operating airline pays monetary compensation to other airlines.

4. Franchised flight: A flight where the operating airline operate only under the designator of an other airline and pays much more monetary compensation.

2 A model of entry in the intra-european airline industry (to be continued)

		Direct [1]	Total leased[2]	Partial leased[3]	Joint[4]	Franchised [5]	Code share [6]
AIR-FRANCE	1995	170	8 (8)[7]	7 (6)	20 (10)	3 (3)	7 (7)
	1999	161	10 (4)	12 (5)	1 (0)	56 (53)	0 (0)
	2000	193	21 (9)	73 (33)	0 (0)	82 (74)	0 (0)
FINNAIR	1995	61	1 (0)	2 (1)	3 (2)	2 (1)	1 (0)
	1999	75	5 (2)	17 (10)	0 (0)	16 (16)	0 (0)
	2000	71	4 (1)	14 (9)	0 (0)	2 (2)	0 (0)
ALITALIA	1995	132	0 (0)	0 (0)	1 (0)	1 (0)	0 (0)
	1999	144	6 (0)	23 (6)	0 (0)	1 (0)	8 (3)
	2000	150	12 (4)	28 (19)	0 (0)	106 (106)	0 (0)
BRITISH-AIRWAYS	1995	135	0 (0)	0 (0)	0 (0)	110 (4)	0 (0)
	1999	151	4 (3)	3 (2)	0 (0)	144 (36)	0 (0)
	2000	162	13 (3)	29 (10)	0 (0)	168 (50)	11 (5)
CONDOR-FLUGDIENST	1995	140	0 (0)	0 (0)	0 (0)	79 (56)	0 (0)
	1999	219	0 (0)	0 (0)	0 (0)	76 (53)	0 (0)
	2000	222	23 (21)	0 (0)	0 (0)	68 (61)	0 (0)
AER-LINGUS	1995	40	2 (2)	1 (1)	0 (0)	0 (0)	0 (0)
	1999	41	1 (1)	4 (1)	0 (0)	0 (0)	0 (0)
	2000	42	3 (2)	3 (1)	0 (0)	0 (0)	0 (0)
RYANAIR	1999	34	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	2000	44	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
IBERIA	1995	115	7 (4)	1 (1)	16 (0)	5 (4)	0 (0)
	1999	132	3 (1)	5 (3)	14 (1)	116 (83)	1 (1)
	2000	120	19 (1)	29 (16)	12 (1)	82 (33)	0 (0)
KLM-ROYAL-DUTCH-AIRLINES	1995	32	0 (0)	2 (2)	4 (4)	25 (4)	0 (0)
	1999	31	18 (2)	37 (6)	3 (2)	29 (16)	1 (0)
	2000	31	9 (0)	35 (10)	0 (0)	31 (14)	0 (0)
LUFTHANSA-GERMAN-AIRLINES	1995	246	0 (0)	0 (0)	31 (4)	68 (51)	36 (5)
	1999	265	7 (1)	53 (11)	4 (1)	125 (85)	120 (17)
	2000	286	126 (90)	128 (44)	5 (1)	155 (139)	8 (7)
OLYMPIC-AIRWAYS	1995	80	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	1999	71	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)
	2000	80	3 (0)	4 (1)	0 (0)	0 (0)	0 (0)
AUSTRIAN-AIRLINES	1995	20	0 (0)	6 (3)	22 (3)	7 (2)	1 (0)
	1999	24	7 (4)	15 (11)	9 (4)	3 (2)	6 (2)
	2000	25	13 (5)	40 (14)	4 (0)	9 (5)	25 (11)
SAS-SCANDINAVIAN-AIRLINES	1995	92	2 (0)	5 (0)	6 (2)	0 (0)	0 (0)
	1999	91	40 (11)	106 (39)	0 (0)	0 (0)	0 (0)
	2000	105	48 (21)	119 (51)	0 (0)	0 (0)	0 (0)
SABENA	1995	50	2 (2)	4 (4)	0 (0)	2 (2)	3 (3)
	1999	61	10 (4)	15 (10)	0 (0)	9 (8)	0 (0)
	2000	58	16 (5)	45 (14)	0 (0)	59 (53)	45 (12)
TAP-AIR-PORTUGAL	1995	50	2 (1)	7 (3)	0 (0)	1 (1)	1 (1)
	1999	51	2 (2)	4 (1)	0 (0)	3 (2)	5 (4)
	2000	57	5 (1)	12 (9)	0 (0)	2 (2)	9 (8)

1: Direct operations flight, 2: Totally leased space flight , 3: Partially leased space flight, 4: Joint operation flight , 5: franchised flight, 6: Code shared flight , 7:Commun routes with direct operations

TAB. 7 – *Distribution of operated routes per airline and type of operation within the european union*

		1995		1999		2000
FRANKFURT	LH	67.5	LH	65.5	LH	63.2
	BA	4.7	BA	4.3	BA	4.5
	AZ	3.3	DE	3.0	DE	2.8
PARIS(C.DEGAULLE)	AF	43.9	AF	70.0	AF	56.5
	BA	11.0	AZ	5.2	LH	6.4
	AZ	9.2	BA	4.3	BA	5.7
AMSTERDAM	KL	35.3	KL	22.5	KL	21.5
	UK(Buzz)	11.2	UK(Buzz)	16.5	UK(Buzz)	15.3
	BA	5.3	EW	7.06	EW	6.8
BRUSSELS	SN	52.4	SN	54.0	SN	38.6
	BA	8.5	TV	12.2	QG	12.3
	LH	5.1	BA	5.6	TV	10.8
PARIS(ORLY)	AF	67.6	AF	57.9	AF	58.1
	IJ	9.8	IJ	17.9	IJ	18.0
	IW	6.7	IW	11.1	IW	10.5
MUNICH(INTL)	LH	60.5	LH	47.4	LH	46.8
	DI	9.1	DI	12.2	DI	12.3
	LT	5.4	BA	4.2	LT	3.8
ROME(FIUMICINO)	AZ	74.0	AZ	66.9	AZ	61.3
	IG	6.8	AP	4.2	AP	6.5
	BA	3.5	IG	4.2	LH	3.6
DUESSELDORF	LH	41.9	LH	33.9	LH	35.5
	LT	17.3	LT	17.6	LT	16.6
	DI	7.4	DI	8.0	DI	7.3
MADRID	IB	49.6	IB	46.6	IB	48.1
	AO	17.9	UX	12.3	JK	14.7
	UX	6.9	AO	10.5	UX	13.6
LONDON(GATWICK)	BA	39.1	BA	40.8	BA	37.7
	JY	10.2	FD	10.3	FD	16.3
	FD	8.2	JY	8.0	JY	7.0
BARCELONA	IB	47.0	IB	35.6	IB	40.0
	AO	16.4	UX	14.6	UX	15.7
	UX	7.0	AO	9.4	JK	9.3
LONDON(HEATHROW)	BA	44.7	BA	45.9	BA	42.9
	BD	16.3	BD	18.9	BD	20.7
	LH	7.1	EI	5.7	EI	5.9
HAMBURG	LH	65.7	LH	45.7	LH	46.1
	BA	4.6	DI	8.2	DI	7.1
	LT	4.1	HF	8.0	HF	7.1
COPENHAGEN(INTL)	SK	58.8	SK	63.0	SK	62.0
	DX	9.6	QI	5.3	QI	5.2
	DM	5.6	DM	5.0	DM	5.1
NICE	AF	49.4	AF	31.0	AF	26.1
	IW	14.1	FU	10.3	FU	16.1
	BA	6.2	IW	10.1	IW	9.3
ATHENS	OA	72.9	OA	54.8	OA	48.6
	AZ	6.1	X5	9.4	A3	13.2
	LH	4.9	AZ	5.8	X5	11.2
STOCKHOLM(ARLANDA)	SK	63.7	SK	60.7	SK	64.3
	TQ	14.1	BU	6.8	JZ	7.9
	JZ	4.1	JZ	6.2	BA	4.6
STUTTGART(ECHTERDINGEN)	LH	50.3	LH	39.4	LH	38.1
	DI	8.8	DE	7.2	DE	6.8
	DE	6.7	DI	6.5	HF	6.7
LONDON(STANSTED)	UK	49.3	FR	33.1	FR	41.6
	FR	28.2	OG	22.4	OG	24.2
	JY	7.9	UK	20.6	UK	10.8

TAB. 8 – *Carrier ASK (available Seat Kilometres) share at selected large hubs (percentage of all intra-european union ASK at hub)*

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EU Accession and Civil Aviation Regimes: Malta and Cyprus as a case study

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Abstract

Aviation deregulation is usually a challenging and demanding task and accession to the European Union requires that all candidate states should harmonise their legislation in the context of the European Common Aviation Area. Malta and Cyprus, the small Mediterranean island-states to join the EU in 2004, will have to abandon any protectionist policies in favour of their flag-carriers and let them survive in a liberal framework. The paper discusses the implications of this regime change for civil aviation in Malta and Cyprus and in addition to the airline industry, it examines the impacts on the complementary tourism sector. Unless carrying capacity limits are understood, the islands may become victims of successful airline liberalisation. The paper concludes by stressing the need for sustainable development and active policymaking.

Keywords: carrying capacity, Cyprus, air transport deregulation, Malta, tourism

1. Introduction

In May 2004 the European Union will admit ten new countries. These entrants vary greatly in population and country size but also in terms of economic, socio-political and cultural background. The impact of their contribution to the European jigsaw is still unknown and in this context their economic liberalisation and integration into the Single Market constitutes one of the major challenges for the future of the Union. The two smallest countries to join the

European Union are Malta and Cyprus. Both Mediterranean island-states have commonalities in terms of their British colonial past (Malta became independent in 1964 and Cyprus in 1960) and their heavy dependence on tourism that accounts for a fifth of their GDP. By joining the EU the two countries will also become members of the European Common Aviation Area (ECAA) that will comprise the twenty-five EU countries plus Norway, Iceland and possibly Switzerland. Carriers belonging to ECAA countries are granted full traffic freedom rights within the Area (including cabotage) and are banned from receiving any form of state subsidy or other preferential treatment by their governments. This may have major implications for civil aviation in Malta and Cyprus as the lack of an internal aviation market and the seasonal character of mass leisure tourism charter flights raised the need for a protectionist regime in favour of the state owned flag carriers in the past (Papatheodorou, 2001). In the post-colonial milieu, Air Malta and Cyprus Airways acted as institutions of social integration and modernisation (Raguraman, 1997) and guaranteed stability of aviation services throughout the year in addition to state participation in the lucrative leisure market largely controlled by the tourism conglomerates of Northern Europe (Papatheodorou, 2002). As elsewhere in the Continent, however, emerging inefficiencies resulted in the gradual relaxation of heavy regulation and the adoption of market strategies by both carriers: participation in the ECAA necessitates further radical changes.

This paper aims at analysing the strengths, weaknesses, opportunities and threats in the new aviation corporate environment of the two island-states with emphasis on their flag carriers. In particular, threats to the two flag carriers by network, charter and low cost carriers are examined and possible reactions are discussed: in addition to the inevitable cost rationalisation, participation in strategic alliances and acquisition by future Pan-European airline groups are examined from a defensive perspective, while from an offensive one emphasis is given on the exercise of fifth freedom rights, development of regional hubs and majority shareholding in other EU carriers. The paper advises policymakers on the above by also taking into account two major issues, i.e. the ongoing political developments particularly in Cyprus and the need to develop tourism on a sustainable basis that will respect the carrying capacity of both island-states.

2. The Case of Cyprus

a. Regulatory Environment and intra – EU Aviation Markets

Scheduled services between Cyprus and the European Union member states are still highly regulated at least de jure: most bilateral agreements allow single carrier designation, double approval of fares and rates and mutual consent on capacity. In the case of Germany, the United Kingdom and Greece the regulatory framework is looser as it allows dual designation on a country pair basis but single designation in terms of airport pairings. London is served by one carrier operating into Heathrow and the other into Gatwick Airport. Nonetheless, Athens and Thessaloniki (the two largest cities in Greece) are excluded from dual designation as only the two flag carriers are allowed to operate (Vassiliades, 2003).

EU accession and entry into the European Common Aviation Area will signify the end of such regulatory constraints. Interestingly, however, the forthcoming liberalisation will not have a major impact for most of the routes. First, the markets have been long liberalised de facto and state interventions are infrequent. Second, as shown in Table 1, most markets are rather small in terms of passengers and a price war among incumbents and new entrants would have a limited effect on the majority of price-inelastic business travellers. Third and perhaps most important, it is apparent from Table 1 that with the exception of Greece all large markets are predominantly related to charter flights. This is not surprising, as Cyprus is largely a leisure destination for the British, the Germans and the Swedish who visit the island on a seasonal basis mostly to enjoy the sea and the sun. Despite any impediments in the past, charter carriers are now largely unconstrained: the main exception is that such flights cannot originate from Cyprus. Having the above in mind, the main effects of liberalisation should be concentrated on the following:

- traffic creation in the Cyprus – Greece and Cyprus - UK markets, i.e. probably the only ones to sustain additional potential players in direct scheduled services
- traffic creation in the above and other markets by charter carriers originating from Cyprus
- traffic creation and diversion by developing an airport hub in Cyprus
- implications for the political re-unification of the island

As expected, all the above will affect significantly the future of Cyprus Airways, the incumbent flag carrier. For this reason the discussion will now focus on the main market players in the country.

b. The Main Market Players

The Cyprus Airways Group is the indisputable dominant player in the market, largely because of the protectionist regime on international flights – there are no domestic services. Cyprus Airways, the main company of the group and the flag carrier of the Republic was established in 1947 with British Airways (44.90%), the Cyprus Government (22.45%) and local investors (32.55%) as main shareholders. Following Independence, Cyprus Airways grew dynamically using the Nicosia International Airport as its base for services to Europe and the Middle East: however, its plans collapsed in 1974 after the Turkish invasion as the carrier was left without aircraft and had to relocate its operations to Larnaca Airport. In 1981, British Airways sold most of its shares to the Cypriot Government, which currently controls about 70% of the company – private investors hold now approximately 25% (Cyprus Airways 2003a). Over the last twenty years, Cyprus Airways developed a second hub in Paphos (on the west part of the island), expanded its network (in 2002 the carrier served 35 airports in 20 countries), enhanced its tactical partnerships and codesharing agreements (at present with KLM, Gulf Air, Alitalia, Syrianair, El-Al, Aeroflot and LOT) and renewed its fleet (with two A319s and two A330s as the most recent acquisitions). In 2002, Cyprus Airways carried 1,654,719 passengers (a 9.9% growth over 2001), had a 73.1% load factor and recorded a loss before tax of C£ 1.2 million (Cyprus Airways, 2003b).

To take advantage of the buoyant leisure market, Cyprus Airways established appropriate companies. Eurocypria Airlines is a charter carrier founded in 1991 that focuses on the main European origin travel markets (with new orders of Boeing 737-800). In 2002, the company carried 497,729 passengers (a 4.3% growth over 2001) and recorded a loss before tax of C£ 1.2 million (Cyprus Airways, 2003b). Cyprair Tours is a specialist tour operator established in 1970 that organises inclusive holidays to Cyprus from the main British cities. Cyprus Airways also owns the Duty Free Shops at Larnaca and Paphos Airports and Zenon NDC, a company that manages electronic information through SABRE. In the financial year 2002, Cyprus Airways Group made a consolidated pre-tax profit of C£ 4.7 million (Cyprus Airways, 2003b).

The other main player in the market is the independent carrier Helios Airways. In May 2000 it started charter services from a number of European origins while in April 2001 Helios acquired license to fly also on a scheduled basis. In March 2002 the carrier commenced regular services from Larnaca to Dublin. At present, however, the charter market is still the

main business of Helios: in 2001 the company carried 221,947 passengers on charter flights as compared to 20,122 in scheduled services (Cyprus Department of Civil Aviation, 2002). The carrier is currently renewing its fleet focusing on Boeing 737-800 (Helios Airways, 2003). During its short presence in the market it has lobbied for full liberalisation and has criticised the government for being overprotective towards the Cyprus Airways Group: for example, in February 2002 the carrier was refused a license for charter flights between Tel Aviv in Israel and Paphos (Koumelis, 2002a). If Helios proves successful in its operations, other new carriers might follow suit. Various plans for charter and scheduled services exist, including those prepared by Capital L Airlines, the subsidiary of the Cypriot tourism conglomerate Louis (Koumelis, 2000a).

c. The effects of Liberalisation on the Cyprus – Greece Market

Greece is the only large aviation market for Cyprus where passengers carried on scheduled flights clearly outweigh those who travel on charter services. Cyprus and Greece have close ethnic (historical and cultural) and business links. For the Greek-Cypriots, Athens and Thessaloniki are the major metropolitan centres of the Hellenic world: they are places suitable to work (Greece is the only EU country where Cypriots can work without immigration control impediments), become educated (the University of Cyprus has only recently started admitting students), be entertained and do shopping. In other words, there is a strong Visiting Friends and Relatives (VFR) and some business-related traffic from Cyprus to Athens and Thessaloniki. The routes between Cyprus - Athens and Thessaloniki are operated on a duopolistic basis by Olympic and Cyprus Airways. Greece accounts for about a third of Cyprus Airways traffic with Athens attracting three quarters of these flows (Cyprus Airways, 2002).

Interestingly, the above-described situation has great similarities with the Ireland -Britain aviation market and in particular the Dublin – London route. British Airways and Aer Lingus were the only carriers serving the route until 1986 when deregulation was introduced. The subsequent entry of Ryanair led to a dramatic reduction in fares, a major increase in the number of passengers and to the eventual exit of British Airways from the market (Barrett, 1997). This scenario could be replicated, therefore, in the context of the Larnaca – Athens (and to a lesser extent the Larnaca – Thessaloniki) route. It should be noted, however, that the level of fares in the Larnaca – Athens route has been significantly reduced over the last few years by Cyprus Airways (Koumelis, 1999), possibly to pre-empt any potential new entry. In

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fact, a price war is unlikely to start from the other incumbent, Olympic Airways, as the Greek flag carrier is in a very difficult financial position and faces severe penalisation by the European Court of Justice for receiving illegal state subsidisation in the 1990s. Similarly, although Cyprus Airways is in a much healthier position, it faces substantial cost rigidities related to strong unionisation and staff expenses: the latter accounted for 32.6% of total operating costs (C£ 52.6 million) in 2002 (Cyprus Airways, 2003b). The carrier has also recently faced adverse publicity for lack of meritocracy (Koumelis, 2003). Therefore, a low cost carrier with a more flexible cost base could initiate flights between Larnaca and Athens pressing fares further downwards. This could be an existing EU airline (such as Ryanair or easyJet) using seventh freedom rights or a start-up company based either in Cyprus or Greece. A traditional EU scheduled carrier (e.g. British Airways) could also consider entering the route but the practice in the Single Aviation Market has shown that such moves have been rather unusual so far (British Civil Aviation Authority, 1998). In any case, the new deregulated environment poses threats for the two incumbent flag carriers, which might experience substantial new rivalry in one of their most lucrative routes.

Despite this threat on direct services between Larnaca and Athens, Cyprus Airways can take advantage of new emerging opportunities in the Greek market. Over the last few years, Cyprus Airways has repeatedly stated its interest to participate actively in the privatisation of Olympic Airways (Koumelis, 2000b), however, the Greek government has postponed any developments at present. Irrespectively of the outcome, Cyprus Airways decided to establish Hellas Jet in May 2002: this new carrier based in Greece will fly to major European destinations such as London, Paris, Frankfurt and Brussels and is expected to start operations in summer 2003 (Cyprus Airways, 2003b). The existing rules within the European Common Aviation Area preclude Cyprus Airways from having a majority shareholding either in Olympic Airways or Hellas Jet, however, the forthcoming accession of Cyprus both in the ECAA and the EU will obviously relax any such constraints. Moreover, the Cypriot flag carrier will soon be able to use fifth and seventh freedom rights in Greece and endow the Republic with flights to new destinations. In particular, in addition to any stand-alone services between Athens (or Thessaloniki) and cities in other EU states, Cyprus Airways will be able to achieve economies of density by filling its aircraft originating from Cyprus with passengers in Greece en route to another EU country. The financial sustainability of all the above operations, however, is an open question as the aviation market in Greece is in crisis: in

addition to the financial problems of Olympic Airways, Axon Airlines went bankrupt in 2001 while Aegean Airlines and Cronus had to merge in the same year to survive.

A final point to consider is the effect of charter liberalisation on the Cyprus - Greek market. Given the expected rivalry among scheduled carriers, its impact will probably be limited in the main routes of Athens and Thessaloniki. Peripheral tourist destinations in Greece, however, may be affected. For example, the relaxation of the seat-only rules (currently limited to 15% of the total available capacity depending on airport) could exercise downward pressure in existing air fares between e.g. Heraklion in Crete and Larnaca. Moreover, the introduction of charter flights originating from Cyprus will probably strengthen the gradually developing vertical integration practices of major Cypriot tourism conglomerates in Greece, such as the Louis Group. In fact, the latter is currently expanding its portfolio of hotels in major Greek islands, such as Zakynthos: the combination of hotel accommodation with a charter flight and perhaps other ancillary services could offer a cheap Greek holiday package to the Cypriot traveller in the near future. In conclusion, although the major implications of air transport liberalisation will probably be seen in the context of scheduled services, any developments on charter flights and the leisure product should not be underestimated.

d. The effects of Liberalisation on the Cyprus – Britain Market
The largest aviation market for Cyprus is Britain and despite the great majority of passengers flying on charter services, the scheduled market is also of respectable size. Cyprus has old colonial links with Britain and in addition to any business traffic there are strong VFR flows due to the presence first of a large Cypriot community in Britain (mostly in London and Manchester) and second of British military bases and other expatriates (usually retired people) in Cyprus. The British market is very important for Cyprus Airways as it accounts for about 24.6% of its traffic (Cyprus Airways, 2003b).

Having the above in mind, the effects of liberalisation can be substantial. In terms of scheduled services, Helios expects to start operations from Larnaca to London Luton in September 2003 subject to appropriate (and anticipated) changes in the current bilateral agreement between Cyprus and the United Kingdom. Other airlines might follow suit when full liberalisation takes place. Still, the market might not be as promising as it looks from a first glance. The Greek experience can be useful in this perspective as despite initial optimism, the Athens – London market is currently facing crisis: South East European

Airways (a Virgin Atlantic franchise) stopped flying between London and Athens in 2001 and Aegean – Cronus the year after. On the other hand, easyJet expanded its operations in 2002 by adding a daily flight from London Gatwick to Athens on top of the two existing ones from London Luton. Nonetheless, the economics of the London – Athens itinerary do not fit the standard low cost model: it is occasionally argued with a sense of humour that easyJet started flying to Athens because of the Greek origin of Mr Stelios Hadji-ioannou, its founder. Moreover, from a strategic perspective the carrier might have introduced the Gatwick flight to secure valuable slots in this airport (after the relocation of British Airways to Heathrow) that can be later used in other more profitable routes.

Therefore, if the Athens – London route can at most sustain three carriers (Olympic Airways, British Airways and easyJet), it is unlikely that the Cyprus – Britain market will be more successful at least in terms of direct flights. Moreover, the long distance between the two countries precludes the introduction of any low cost carrier de facto. Given the situation in Greece, Cyprus Airways might find it difficult to use fifth freedom rights from Greece en route to a British destination: Hellas Jet, its subsidiary, might also face problems if it decides to feature London as a destination although some feeder services from Athens to Cyprus (and vice versa) could perhaps alleviate the problem. Cyprus Airways could also use fifth freedom rights in another EU city (e.g. Rome, Vienna or Paris) to boost its Cyprus – Britain markets but this is unlikely to materialise in practice.

Compared to the Greek market, the impact of charter services liberalisation might be larger. In fact, Britain is the most significant tourism origin for Cyprus and the abolition of the current restrictions on seat-only packages will probably enhance competition and reduce the level of fares: increasingly, more people in Britain prefer to make their own travel arrangements (Thomson, 1999), while the existence of friends, relatives and second homes in Cyprus discourages at present some travellers from booking a package that includes accommodation as a compulsory element. The Cypriot based charter airlines have a good presence in the British market and will probably survive in fiercer competitive conditions if they also take appropriate cost reduction strategies. In 2002, Eurocypria flew about 128,000 passengers from Britain to Cyprus with a market share close to 14% and Helios flew about 66,000 passengers accounting for 7% of the market (Cyprus Tourism Organisation, 2003). Figures very close to Helios were also reported by Excel Aviation, a subsidiary of Libra Aviation, which is a company of essentially Cypriot interests. Moreover, the development of

charter services originating from Cyprus could lead to a decrease of existing fares quoted by schedule carriers.

e. The Impact of Liberalisation on the other Markets

As argued earlier in the paper, the impact of liberalisation on the aviation market for services between Cyprus and the remaining EU countries will be rather limited, as routes are either thin or almost entirely of charter nature. Same conclusions hold for routes between Cyprus and the other states that will join the European Union in 2004 as shown in Table 1. The latter also reveals that Cyprus has significant traffic with other European countries such as Switzerland and Russia as well as with most of the countries in the Middle East. Though this traffic will not be directly affected by the EU accession of Cyprus, there might be some indirect effects in the future if the European Commission is finally granted the power to negotiate traffic rights collectively with third countries. Such a development will undoubtedly strengthen the bargaining power of Cyprus and might also have an impact on sixth freedom rights and the emergence of Cyprus as a regional hub.

In fact, Cyprus Airways seems to have realised the strategic geographical location of the island for transit traffic to Middle East and the Gulf countries. For this reason, the carrier has recently furthered its operations to Paris that accounts now for 50% of its total transit traffic (Koumelis, 2002b). Nonetheless, to develop a regional hub and acquire features of centrality and intermediacy (Fleming and Hayuth, 1994), Cyprus should first renovate its airport infrastructure. Larnaca International Airport accommodated 4,972,758 passengers in 2002 but only 5.5% of these were transit; similarly Paphos International Airport recorded 1,587,057 passengers of which 4.9% were transit (Cyprus Department of Civil Aviation, 2003). At present, the Larnaca Airport seems unable to win the regional 'war of hubs' where it faces serious rivalry by the airports in Athens, Beirut and Istanbul: it has maximum capacity of 7.5 million passengers, a single runway and passengers cannot continue their journey to Turkey due to existing political situation (Butt, 2001). In 2001, the Cypriot government received ten offers by international consortia to renovate the two airports on a Build – Operate – Transfer (BOT) basis (Koumelis, 2001). A decision was expected in early 2003, however, the change of government has postponed any plans for the time being. Still, the aviation legislation has been recently harmonised with the *Acquis Communautaire* on issues of airport ownership and operation, ground handling services, economic regulation and allocation of slots (Official Journal of the Republic of Cyprus, 2002).

In its effort to become a regional network carrier and in addition to any airport infrastructure improvements, Cyprus Airways should seek active collaboration with other carriers. Individual codesharing agreements can be useful, however, the airline should seek entry into one of the main strategic airline alliances, such as OneWorld, Star Alliance or Sky Team. In fact, none of the three has a partner in Eastern Mediterranean or Middle East and EU accession of Cyprus renders the flag carrier a potentially attractive option. Of course, if the long-awaited market structure consolidation in the European aviation industry materialises, then Cyprus Airways could be bought by one of the major surviving carriers that lead the strategic alliances in Europe. Before this happens, however, the company should overcome its state-owned nature and increase its shareholding basis through a privatisation programme. As past European experience has shown, such issues always raise conflicts: the Cypriot case, however, is more complicated due to unresolved political issue on the island.

f. Political Issues

Since the 1974 incidents, the island of Cyprus has been de facto partitioned in two areas, i.e. the Republic of Cyprus controlled by the Greek Cypriots in the South and the northern part governed by the Turkish Cypriots. The latter declared an independent state in 1983, which is only recognised by Turkey and Pakistan. In fact, the northern part is politically isolated; it has no international relations and its airports are regarded as illegal points of entry to Cyprus by the Republic. Consequently, travellers can only fly to the northern part by making a stopover in Turkey, incurring extra time cost. If they wish subsequently to visit the South, they should first go to a third country, e.g. Greece: there are no flights between Turkey and the Republic of Cyprus as the two countries have not even exchanged first freedom rights! In other words, politics have dramatically distorted transport geography and accessibility on the island. Nonetheless, the decision over the EU accession of the Republic of Cyprus in May 2004 may lead to an entirely new political situation, as the Turkish Cypriots are pressed by the international community to follow Greek Cypriots and accept the resolution plan proposed by the United Nations. In essence, the latter suggests the re-unification of the island under a federal status.

The potential success of this plan will have important implications for civil aviation in Cyprus. The emerging détente will enhance political stability leading to new investments and further tourism development of the island: consequently, air traffic flows will grow.

Moreover, the initiation of direct flights between the new Republic of Cyprus and Turkey could facilitate the development of an international hub on the island. Despite this rosy image, however, there are some controversial issues to resolve. The first is related to the flag carrier and the associated traffic rights. At present there is Cyprus Airways in the Republic and Cypriot Turkish Airways in the north: which company will be regarded as the flag carrier of new Cyprus and under what terms and conditions? The second concerns airport development. As argued earlier in the paper, the Republic is in train to renovate Paphos and primarily Larnaca Airport: such a decision, however, would further intensify the existing provocative asymmetry between the South and the North in terms of economic and air transport development. As a reaction, the Turkish Cypriots plan to renovate Ercan Airport: however, the size of the market renders absurd the creation of more than one international hub, while the renovation of the abandoned Nicosia Airport (as a middle solution) might prove a very expensive project. These issues are important and will undoubtedly play a crucial role in future negotiations: the re-unification process of Western and Eastern Germany can perhaps provide a useful benchmark in this perspective.

3. The Case of Malta

As a British Empire military base, Malta's economy prior to achieving independence from Britain in 1964 was dominated by its need to supply dry-docks maintenance facilities for the British Navy. The Maltese economy was still highly dependent on Britain in the early 1960's, and economic development was far behind that of its northern European neighbours. Recognition of the need to diversify Malta's "fortress economy" led to a rapid development of new industries in the light manufacturing and service sectors from the 1960's onwards. By 2003, following years of national division and local debate over the merits of EU membership, the centre-left Nationalist government succeeded in winning a "pro EU entry" referendum and cemented this win with a general election victory shortly after for a further five-year term in office. Accession into the EU is planned for May 2004, and expectations followed that entry into the "Eurozone" (replacing Malta's own Lira currency with the Euro) might materialise three years after accession – within the same term of office of the new Nationalist government.

a. Tourism and the Evolution of the Civil Aviation Regime in Malta

As part of Malta's economic diversification programme, tourism grew rapidly from the 1960's, and the Maltese landscape was transformed over the course of a few decades through intensive hotel development. Mass tourism charter flights to cater for a growing demand for tourism into Malta began during the late 1960s. When Air Malta started operating in 1973, one of its early objectives was to increase tourism inflow from richer European countries, with UK, France, Germany, Netherlands and Italy emerging as the top five supplier markets to Maltese tourism. Air Malta was a government owned carrier, with a mission to increase tourist arrival numbers so as to support the growing tourism economy.

Strong traffic growth in recent decades has resulted in a situation where tourism is now a major contributor to the Maltese economy (24% of GNP according to a study by Mangion and Vella, 2000), and an important element of the new service sector. Tourist arrival numbers soon reached very high levels very quickly for a small and densely populated country. A Maltese population of 0.4 million residents now receives 1.2 million tourist arrivals per year. A carrying capacity assessment by Mangion (2001) suggests that Malta cannot take any more tourist arrivals and that a level of saturation has now been reached.

By 2003 the Republic of Malta had already liberalised air service agreements with four EU countries (UK, Germany, Netherlands and Eire), no air service agreements at all with four accession countries (Estonia, Latvia, Lithuania, and Slovenia), and restricted air service agreements with all the other current and accession EU countries. Its accession into the EU during 2004 and the associated liberalisation of Maltese civil aviation within ECAA will result in the removal of many restrictions in its civil aviation markets (e.g. single carrier designations, flight frequency limits and tariff approval processes which currently exist regarding air transport operations with many European countries). If the market cannot get bigger, and if a consequence of EU membership is that the Maltese government is unable to maintain protectionist policies to cushion its (still predominantly government owned) national carrier from competition, then competition in air transport to and from the Maltese islands may intensify, as carriers seek to erode Air Malta's dominant position in the market place (more than half of all civil air traffic into and out of Malta is currently carried by Air Malta).

b. Competition between Air Malta and carriers originating from other EU countries

Air Malta - given its low cost base compared with European airlines it competes with on the Malta route - has historically done well to fight off competition from its northern neighbours. Though it has been characterised as over-manned, over-unionised, and over-protected as a largely government owned carrier, comparative labour rates are such that it remains nevertheless, low-cost compared with many of its European flag-carrier counterparts (which can also be characterised as over-manned and over-unionised but at much higher pay levels). Air Malta is also relatively well managed by European standards, and it is financially self-sustaining – it is not a drain on the Maltese taxpayer in the way that many European flag carriers are on their taxpayers.

As far as competition from European low-cost carriers is concerned (e.g. Ryanair and easyJet from the UK), Malta's three-hour flight-time from the UK puts it out of single-sector range of the UK's low-cost-carriers, which prefer to operate within a 2-hour sector-range so as to maximise aircraft turnaround opportunities within a 24-hour time period and thereby maximise asset utilisation. Though Ryanair and easyJet are considering establishing central European hubs, and though conceivably the establishment of a north Italian hub near Milan could bring Malta within connecting traffic range of high-frequency, short-sector, northern-European cities; it is thought that the great majority of tourists to Malta will be prepared to pay a premium to fly direct point-to-point services (e.g. London-Malta direct at a higher fare, rather than London-Milan-Malta at a lower fare). Despite the common misconception that low cost carriers only serve point-to-point and do not cater for connecting traffic (according to Jeans (2002), 17% of Ryanair's 2001 traffic at Stansted comprised connecting passengers – i.e. passengers who bought two individual fares to make up their own connecting journey, e.g. Dublin-Stansted-Paris), the majority of mass-market, holidaymakers to Malta are seeking the convenience of a one-stop-shop package which includes a point-to-point air travel component. Comparatively small numbers of connecting passengers will find a cheaper way of getting to Malta on combined low-cost-carrier services, but these are not expected in sufficient numbers to cause Air Malta major problems.

c. Competition between Air Malta and other carriers which may originate from Malta

Though Air Malta is well placed to see off competition from its more expensive and arguably less efficient northern European neighbours, it may however, find increasing competition at home. Maltese entrepreneurs such as Robby Borg of Bargain Holidays Ltd may take

advantage of liberalisation opportunities post May 2004 through the establishment of new, home-grown competitors to Air Malta which could be even lower cost than Air Malta is now. Borg suggests that "although Air Malta will continue to enjoy a monopoly in terms of providing Maltese originating air services this cannot continue after May 2004" (Busuttil, 2003). He has already been prevented from establishing a new Maltese based airline called European Air Bargains – a Maltese government decision which was brought to the attention of Neil Kinnock, the EU's Transport Commissioner. Borg already attempts to undercut Air Malta by offering the Maltese public discounted flight-only fares from block-bookings he has with existing UK charter carriers via a retail outlet in Malta's capital and via his internet booking site www.bargainholidays.com.mt.

Clearly the numbers of tickets sold is still small scale compared with Air Malta's current Malta-originating traffic levels but the Maltese flag carrier may need to consider how big a potential threat Borg could be. Though Malta-originating traffic numbers are small, if European Air Bargains is successfully launched after May 2004, Borg may start to build up a customer base from the major tourist supplier markets to Malta large enough to cause Air Malta some problems. A future "European Air Bargains" airline based in Malta might provide significant competition to Air Malta for the provision of block-space bookings of airline seats to northern European tour operators, a market which is crucially important to Air Malta since it represents the majority of seats sold on Air Malta flights.

d. Other competitive pressures on Air Malta

It is not only Air Malta's privileged position in the air that could be challenged. Air Malta will also lose its monopoly on the supply of ground handling services at Luqa airport, and EU procedures for the non-discriminatory allocation of airport slots may also erode some of Air Malta's previously held operational advantages. Air Malta is likely to come under pressure to restructure in order to address its problems of over-manning in the face of such competitive threats. EU pressure to discourage the Maltese government from bailing out Air Malta from any financial problems it may face along the way will add to pressures for Air Malta to privatise, restructure and improve efficiency. In Air Malta's favour however, is that it does benefit from a professional management team, which is well aware of its need to continuously improve performance in the face of increasing competition. Air Malta has a history to date of demonstrating a long-term trend to profitable operations without the need to resort to seeking financial assistance from its government. Air Malta has also proved itself in the past by

competing successfully in a marketplace populated with highly competent carriers such as British Airways and Lufthansa, so it should find itself well prepared to face up to the challenges and difficulties ahead.

4. Carrying Capacity in Malta and Cyprus

The demand for air transport services is essentially derived as most people fly to participate in certain activities in a place away from their origin. Tourism plays a major role for Cyprus and Malta and as the previous analysis indicated, the forthcoming aviation deregulation will enhance tourism flows. But is such development sustainable or is it likely to exceed the carrying capacity limits of the two island-states causing environmental and other destruction that would outweigh the benefits of liberalisation?

Entrepreneurs such as Robby Borg are lobbying the Maltese government with a view to trying to persuade them to allow a dramatic increase in tourist arrival numbers in Malta. Borg does not believe that 1.2 million tourist arrivals per year represent a capacity limit. He wants to see numbers rising to 1.7 million over a five-year period (he believes that his company can grow the market by 100,000 per year). His views are in conflict with a range of stakeholders in Malta who are keen to keep tourist arrival numbers down and yields up. Similar discussions and friction are also apparent in the Cypriot context.

a. Challenging assumptions regarding the tourist arrivals capacity limit

There are essentially two schools of thought regarding tourism planning on Malta that can be characterised as follows. First, there is the *pile-it-high-and-sell-it-cheap* philosophy. Its advocates suggest that 3* hotel capacity should be expanded – that the bottom end of this highly price-elastic market is the place to make money. Large scale, low-cost hotels with cheap bars and swimming pools are what the great majority of holidaymakers to Malta (and certain resorts in Cyprus) are looking for. Interestingly, planned upgrades (overbooking lower class product sales when higher class demand is low with a view to giving someone a 4* room for the price of a 3* holiday) do not tend to work well in the hotel market in the way that they work in airline sales: whereas many people would relish the prospect of a free upgrade to business class on an airline, someone looking forward to the consumption of cheap food and beverages in a 3* hotel might not be grateful for being transferred to a more expensive environment, even if it does come with a nicer bedroom. The supply sector (e.g. brewers,

caterers selling their products to hotels) also subscribes to this view, often preferring to win higher-volume lower-margin supply contracts with 3* hotels which might prove more profitable than lower-volume higher-margin supply contracts with 5* hotels.

The second philosophy stresses product quality improvements and focus on the high yield sector. Malta and Cyprus are essentially price-elastic holiday markets – and that's their problem (say critics of "pile it high and sell it cheap"), they need to change and move more up-market. Overcrowding makes a stay on an island less enjoyable for its visitors and consequently lowers the prices charged for services. It also becomes a less enjoyable experience for the residents who complain that their home is being "invaded", rather than celebrate the fact that foreign visitors are bringing in much needed hard currency. By only allowing the development of 5* hotels on the two island-states, and by converting existing 3* hotels to retirement homes and apartment blocks, Malta and Cyprus could become less congested while tourism revenues will be maintained because yields will improve (a higher price can be charged for a premium product).

Resolving which is the "best" strategy to pursue for Malta and Cyprus (or which mix of the above approaches is optimal), will entail the application of sensitivity analyses and evaluations of the impact of relaxing a range of "hard" and "soft" constraints in a model. This should be designed to identify the optimal mix of capacities/prices in the overall Cypriot and Maltese tourism economy such that revenues are maximised for the economy as a whole rather than just favouring one sector such as air transport or hotel and catering.

b. Hard constraints on the expansion of tourist arrivals

First, there are energy supply considerations. Can the power plants on the two island-states generate enough electricity? This is probably the most binding constraint. Power consumption among tourists requiring air conditioning and other amenities can be very high. Expansion beyond the 1.2 million visitors level in Malta might prove expensive in terms of the need to expand power plant output and might be infeasible if the development of a new power plant is required. Second, there are water supply problems. In this case, we need to consider whether the desalination plants on the islands can generate enough potable water. This might not be as critical as the electrical power constraint but it also needs serious consideration.

Third, there is an issue of land supply. Robby Borg, for example, advocates the replacement of existing small-scale 3* hotels with the development of fewer but larger (more commercially efficient) 3* hotels with swimming pools and capacities in excess of 400 bedrooms. Malta is a very small country and this may prove difficult to achieve on the scale advocated by Borg. The current planning philosophy advocates granting planning permission only to 5* developments and high-yield boutique hotels, with a preference for converting existing 3* hotels to retirement homes and apartment blocks. Cyprus is larger in terms of size and has greater flexibility to diversify its construction activities and tourist products (e.g. development of rural or mountainous tourism). Still, the introduced upmarket tourism policies have occasionally failed or even accentuated the problems caused by conventional mass tourism (Ioannides and Holcomb, 2001).

c. Soft constraints on the expansion of tourist arrivals

The first important factor to consider is the residents' concerns regarding increased congestion from tourism. Malta already becomes very crowded during the peak visitor months of July and August, especially in the conurbation around Valletta towards the east of the island which is very heavily populated by local residents. The quality of the Maltese road network is poor, car ownership is rising quickly and roads are becoming congested. Advocates of expanding the 3* sector on the Qawra/Buggibba peninsula towards the north of the island, however, suggest that most of their 3* customers are more interested in cheap beer and discos and coastal attractions within walking distance of their Qawra/Buggibba hotels than they are in hiring cars and exploring museums and cultural attractions in the conurbation around Valletta. The implication is that though July/August crowding is currently a problem, it might not get significantly worse. The additional 3* tourists – they argue - will probably remain concentrated around the Qawra/Buggibba peninsula. Furthermore, they suggest that as the quality of the road network improves (perhaps with help from EU structural funds post May 2004), and as the quality of the public transport service improves (new, improved buses and bus services are already being introduced to replace Malta's ageing bus fleet), Malta's congestion problems might even ease to some extent. It remains to be seen whether EU structural funds will materialise, whether new buses, bus routes, park-and-ride schemes will help, and whether 3* visitors really do confine themselves to tourist complexes.

There are also substantial residents' concerns regarding the cultural impact of tourism. The argument that most tourists largely keep themselves to themselves is not one which will find

much support among those Cypriots and Maltese concerned with the erosion of traditional values among the youth. Malta (and also Cyprus to a large extent) is a deeply religious country, with strong family values. Some Maltese consider tourists a bad influence on local residents and would be particularly worried about an expansion of the 3* end of the market rather than the 5* end of the market, since they would be quick to characterise 3* customers as being partly responsible for an increase in licentious behaviour and alcohol and drug consumption among Malta's youth. They do not see raucous behaviour and loud partying as being confined to the Qawra/Buggibba peninsula – the St Julians/Paceville district towards the north end of the conurbation around Valletta is itself a centre for discos and bars and nightlife which is popular among both Maltese residents and tourists alike. It should be noted that such traditional attitudes are not only found among a few old-fashioned "fuddy-duddies" who represent a tiny constituency – many Maltese disapprove of soft-drugs, drinking to excess, pre-marital-sex, topless-sun-bathing etc and would see mass-tourism as part of the problem. This is a complex issue however since many Maltese would also consider tourism to be an essential component to the Maltese economy. A study by Mangion (2000) showed that 71% of the Maltese people considered tourism essential, with a further 28% considering it very important to the Maltese economy. This study showed that the main perceived benefits of tourism are improved economy, job opportunities, cultural exchange and attaining recognition from other countries; with the main perceived problems being pressure on the infrastructure, traffic/parking, overcrowding, increase in prices, deterioration of values and beach related problems.

5. Conclusions

EU membership will result in increased competition in a more liberalised civil aviation regime in Malta and Cyprus – but this should not necessarily imply a massive expansion in terms of tourist arrivals numbers. The Cypriot and Maltese governments will still be able to exert a certain amount of control and strategic direction on the development of their tourism industry through the regulation of planning permission for the development of the islands tourism infrastructure, but a lot of attention has to be paid to considering what is the best size and mix of different elements of the tourism product. The most rational way of reaching a conclusion, which maximises utility for the majority of organisations and stakeholders in the two economies, is to apply forecasting and optimisation techniques to the problem - as in the case of the airline industry, revenue management techniques might help.

Revenue management is the integrated control of capacity and price through the application of demand forecasting techniques at varying price/quality levels, and the subsequent application of price mix optimisation techniques to those forecasts so as to maximise overall revenues. The application of such techniques might also suggest better pricing strategies to help smooth to some extent some of the peaks and troughs in demand (seasonality has a major impact on employment and asset utilisation in Cyprus and Malta, with many hotels having to close during winter as a consequence of insufficient demand at current winter price levels). Apart from package price, another factor to consider in a model aimed at optimising revenue contributions to the overall Cypriot and Maltese economy will be length of stay. It could be shown that on a per-day basis, short stay visitors spend more than long stay visitors. This suggests that during peak periods (e.g. summer) more one-week holidays rather than two-week holidays should be sold, and during trough periods (e.g. winter), discounts should be available for very long visits (e.g. there is a market for retired northern Europeans to fly south for extended winter breaks of one month or more – such trips can prove very cost effective for them in cost of living terms, considering the costs of staying at home and paying their heating bills).

Apart from considering absolute numbers (i.e. demand in terms of number of tourist arrivals on the islands – capacity constraints discussed suggest that these numbers might not necessarily increase in any case), the quality and value dimensions might be improved benefiting tourists arriving in Cyprus and Malta and making the two island-states a more attractive tourist destination for potential EU visitors. Deregulation of civil aviation as a result of EU accession might also mean that Cypriot and Maltese residents departing the island for holidays in Europe would also benefit from the lower prices offered by new operators. It is suggested that tourism planners in Cyprus and Malta need to adopt strategic revenue management techniques to better optimise tourism resources to maximise revenue opportunities. Whether this should be from a stable tourism arrivals numbers base or a growing tourism arrivals numbers base remains to be seen. Improvements in the tourism attributable contribution to the Cypriot and Maltese economy may not necessarily come from more tourists but from a better mix of tourism arrivals by hotel class, time of year and length of stay.

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Table 1 – Arrivals in Cyprus by Air in 2002

Countries	Charter Tourist Arrivals	Air Traveller Arrivals	Charter Share
UK	931.658	1.354.156	68.80
Greece	5.059	396.820	1.27
Germany	122.147	189.357	64.51
Sweden	95.126	95.897	99.20
Netherlands	17.597	66.377	26.51
Norway	52.581	49.273	106.71
Finland	2.475	45.941	5.39
Austria	8.473	43.315	19.56
Ireland	29.857	41.709	71.58
France	2.841	38.179	7.44
Denmark	30.990	34.301	90.35
Italy	356	27.230	1.31
Belgium – Lux	10.657	23.117	46.10
Spain	71	1.138	6.24
Portugal	n/a	0	
Iceland	n/a	0	
Total ECAA	**1.309.888**	**2.406.810**	**54.42**
Czech Republic	13.866	35.309	39.27
Hungary	2.907	24.590	11.82
Poland	10.473	21.040	49.78
Slovakia	1.916	4.674	40.99
Baltic Countries	2.156	1.188	181.48
Slovenia	48	n/a	
Total New EU	**31.366**	**86.801**	**36.14**
Russia	97.199	161.749	60.09
other CIS	6.732	n/a	
Switzerland	43.538	74.317	58.58
Lebanon	n/a	41.198	
Egypt	n/a	37.007	
Israel	8.913	33.873	26.31
UAE	n/a	23.021	
Syria	n/a	20.765	
Bulgaria	139	20.330	0.68
Romania	426	10.427	4.09
USA	0	0	
Total Market	**1,520,930**	**3,028,939**	**50.21**

Source: Cyprus Tourism Organisation (2003) and personal calculations

Notes: ECAA refers to European Civil Aviation Area (i.e. the fifteen European Union countries plus Norway and Iceland) and Lux to Luxembourg. The Baltic Countries are Estonia, Lithuania and Latvia. Total statistics for the new EU countries do not include Malta. Where data are not available (n/a) a zero value is assumed.

The second column (*Charter Tourist Arrivals*) shows tourist arrivals on charter flights by nationality, whereas the third column (*Air Traveller Arrivals*) shows arrivals by air (excluding excursionists) and country of flight origin. Consequently, the two columns are not directly comparable and it is possible to have a *Charter Share* (the ratio between numbers in columns two and three) that exceeds 100% (as for Norway). Still, the assumption that somebody flies to Cyprus on a charter carrier from their own country is very plausible, i.e. nationality in column two coincides with country of origin of flight: therefore the fourth column is informative.

The Table refers to arrivals, but since the great majority of passengers buy return tickets the total Cypriot air transport traffic is about twice this size. In fact, the year closed at 6.03 million travellers (Cyprus Tourism Organisation, 2003).

Auctioning airport slots (?)

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Abstract

The current allocation of slots on congested European airports constitutes an obstacle to the effective liberalisation of air transportation undertaken in Europe. With a view to favouring efficient slot utilisation and competition, as is the goal of the European commission, we propose to use a market mechanism, based on temporary utilisation licences. In order to allocate those licences, we propose and describe an iterated combinatorial auction mechanism where a percentage of licences would be reallocated each season. A secondary market would also be set up in order to reallocate slots during a season. Since a combinatorial auction involve a complex optimisation procedure, we describe how it can be made to work in the case of auctions.

Keywords: slots, airports, licence, auctions, combinatorial

Introduction

Air transportation has been liberalised in the European Union in 1997, after a few years of transition. It seems, however, that so far, the effects on competition are not as important as they have been in the USA, after the deregulation in 1978.

One of the key factors impeding competition in Europe is the lack of airport capacity at major airports for takeoffs and landings. Because of this capacity shortage, in Europe authorities decided to limit the number of takeoffs and landings to a specified number per hour at certain airports corresponding to the runway capacity. A slot is then defined as "... the scheduled time of arrival or departure available or allocated to an aircraft movement on a specified date at an airport co-ordinated under the terms of regulation...".

In Europe, airport slots are allocated following the "grandfather rights" rule, which is the historic rule prevailing before liberalisation. According to this rule, an airline using a slot during one season keeps it for the following season, as long as the slot has been properly used ("use it or loose it" rule). Available slots are given as a priority to new entrant airlines. But since very few slots become available each season, this leads to a very conservative allocation.

This rule enables stability in the market but by preventing entry of new airlines, it falls short of the deregulators expectations to promote competition in the airline industry. In the following article, we consider the situation from the point of view of the European Community and we assume that the objective[1] is to favour efficient slot utilisation and competition[2].

It is therefore vital, from the European commission point of view to study alternative allocation rules, either administrative or market based rules, to prevent the liberalisation process from stalling

This is what this paper proposes to do, after reviewing the way the current processes (in Europe and in the USA) function, and the shortcomings of the current (part 1). We first examine the question of the nature and property of the slots, and propose to define the slot as a temporary utilisation licence (part 2). In part 3, we review the objectives of the slot allocation and justify the choice of a market mechanism for allocating slots.

One solution, the designing of auctions for slots is more thoroughly studied: auctions are presented and auction design discussed in part 4, and a possible mechanism based on combinatorial auctions is proposed in part 5.

In the conclusion, we review our findings and intuitions, and discuss the problem of acceptability of a market-based mechanism for allocating slots

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[1] Other political objectives could no doubt also have a role in the decision as to whether or not one slot allocation system should be adopted rather than another.

[2] The choice concerning the level of regulation or liberalisation of the air transport sector involves arbitration between the interests of the various groups of society, and we do not intend to enter this debate which seems to have been settled some time ago (although this in no way means that a political decision in the future cannot reverse the tendency, even though such a perspective seems highly improbable at the present time).

1-Airport slots today: the current system and its shortcomings

The current system prevailing throughout the world for allocating slots (except in the USA for domestic slots, as we shall see later on), is the "grandfather right" rule. Basically, the outline of this system is the following: airlines are allocated the same slots each season, as long as they really use it ("use it or loose" it rule). In Europe this system is based on the EC rule 95/93 [règlement CEE n°95/93 du Conseil des Communautés Européennes]. It is not our goal to give a complete description of this system, but rather to outline its main features. For a more thorough description of this allocation system, see for example "allocating airports slots" [7].

The EC rule is an adaptation of the former pre-liberalisation system, and has been adopted to clarify the rules of allocation throughout Europe. Although it has harmonised the allocations throughout Europe, it fails to reach an economically efficient allocation, because slots are not attributed with the objective of maximising benefits for air services consumers or the economy.

Furthermore, despite the fact that a part of the available slots is reserved for newcomers on the airport, the European procedure for assigning slots on saturated airports constitutes an entry barrier and restrains competition. This is because, according to the grandfather rule, only a small number of slots are potentially reassigned to new airlines. Those not wanted by the incumbent airlines and those not properly used, falling under the "use it or loose it "rule, are put into a pool; half of the pool slots are then reattributed to newcomers. This amounts in general to very few slots each season.

In the USA, the grandfather right rule existed before deregulation on a few airports[3] (others being "self-regulated" through congestion). After the 1978 deregulation, the federal Authorities tried to find a new rule, more consistent with the objectives of deregulation.

They set up a system on four saturated airports, which assigned the property of the slots to the airlines, and allowed those airlines to sell their slots to one another (the 1985 "buy and sell" rule). The results of this experiment were not conclusive: The number of slots sold was relatively small, and the sales tended to increase concentration. This is not particularly surprising, since nothing was done to ensure that a large number of slots would be put up for sale and that the sales would favour newcomers. The reason for this is that, as the demand for slots is increasing on such airports, airlines are tempted to retain slots that they do not really need, either for later use or in order to be able to sell them at a higher price. Furthermore, for as long as there is no real possibility for airlines to enter the airport by directly acquiring a sufficient number of slots, it is hardly surprising that it is the airlines already there who buy up any slots that are up for sale.

Finally, if both systems have the advantage of succeeding in allocating slots each season, and provide airlines with a certainty over future allocation, they fail to allocate them efficiently, in a way that maximises benefits for consumers of air services. It is so mainly

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[3] Four airports are concerned today : New York Kennedy, New York La Guardia, Washington National, and Chicago O'Hare

because they are rigid and prevents changes, they distort investment incentives[4] (by giving the slots for free and forever), and above all they allocate slots arbitrarily (no economic criteria).

2- Property rights, the slot as a temporary utilisation licence

2.1 Property rights for slots

In view of the currently imprecise legal aspect, some organisations - including airports - turn to the state for a more precise definition of who owns the property rights for slots. If such a question exists, and if it is up to the State to settle it, then the question is meaningless: Slots belong to the state de facto, and the state is entitled to give them away or sell them if it wants to. In view of the capital strategic importance of this type of asset, we feel that it is increasingly important that the state should retain these property rights and simply grant rights of use for certain specified periods[5].

The reason behind this debate is obviously to define who should benefit from the income connected with the possible sale of the slots. This question results from a political choice, and it is not up to us to give our opinion. However, assuming that the state decides that airports - for example - should benefit from the advantages connected with the use of slots, it would be preferable to set up a system which aims to assign the slots in an efficient manner, and then to enable the airports to benefit from the corresponding income, rather than giving them the property rights directly.

We should note, in passing, that if airports became the owners of the slots, they would not have any incentive to invest in an increase in their capacities, because they would not want to affect the income they would derive from the rarity of the slots. This comment remains valid if a decision is made to transfer the entire income of the auction to the airports. If the decision is made to give the benefit if the income generated by the slots to one of the players in air transport, every effort should be made to do this through fixed transfers, i.e. transfers which are not dependent on the income actually generated.

2.2 The slot as a temporary utilisation licence

We saw that with the grandfather right rule, only a small number of slots are reattributed each season. Even in the case where all the slots of an airline are put back into the pool of slots to be distributed (which is the case of Air Lib in Orly), the current procedure consists in redistributing all the slots formerly belonging to a single airline to several other airlines, thus

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[4] They can give incentives to invest for example in marginally profitable routes in order to keep the slots ("baby sitting" of slots)

[5] The usual argument used to justify transferring property rights for a resource from the state to a company is that it encourages the company to set up specific investments: If the company has no guarantee that it will retain the right to use the resource, it is unlikely to finance investments which are specific to that resource despite the fact that it would be efficient for society. In the context concerned herein, we nevertheless feel that this argument is of minor importance.

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reinforcing the positions of the dominant airlines on the airport. Finally, if we consider the fact that there is often a minimum number of slots that an airline must obtain on an airport for that airport to be a cost-efficient destination (due to the frequency effect, for example), it is clear that for competition to be effective in terms of entry onto an airport, it is necessary to be able to reallocate, on a fairly regular basis, a considerable number of the slots on each airport.

This is why we recommend that the grandfather rule should be progressively dropped, that airlines should be given temporary licences to use slots[6] (5 to 10-year licences, for example), and that they should be allowed to sell those licences. Progressively, of course, because we must not upset the stability of a system which - although not perfect - does have the advantage of working. We could, for example, attribute 10 % of the existing licences every year for ten years (at the end of this period, the initially attributed licences would be due for reattribution, and so on). We are not giving any recommendation, at this point, concerning the method to be used for the initial allocation of the slots, as this will be discussed in subsequent chapters. We are simply pointing out that this procedure should make it possible for new airlines to obtain sufficiently large sets of slots to enable them serve the airport efficiently

Furthermore, limited-period licences would encourage airlines to sell off the slots that they do not really need - or that other airlines could make better use of - rather than keeping them for the future.

To summarise, we recommend, above all, that temporary licences to use slots should be regularly reassigned, and that airlines should be allowed to sell them according to a system which enables new entrants to set themselves up properly on an airport.

3- The objectives of a slot allocation, choice of a market mechanism

3.1 Objectives of a slot allocation

Whatever system is used to allocate slots, it has to be judged by the benefits it brings to the economy. More precisely, the air services resulting from this allocation provide some level of "social welfare" to the customers and to the rest of the economy (including some profit to the airlines).

The optimal allocation is the one that brings maximum benefit for society. But it is not sufficient, because what is optimal at one point in time, may not remain so for long: the allocation should also be capable of evolving, in order to re-allocate the slots to the most efficient use.

Slots are efficiently allocated when used by the airlines that can generate maximum social benefit from them. We can consider, in a competitive situation, that if an airline thinks it will make large profits by using a slot, this fact tends to indicate high demand and low costs, and therefore a high profit is a reliable indication of a large social benefit.

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[6] This is only an example, and studies should have to be conducted, as to the optimal proportion of slots to attribute each season, and how to select them. We feel however, that the right duration would be between 5 to 10 years, so that 10 to 20 % of seasonal slots should be reattributed each season.

In order to approximate this optimum, we can then target the intermediary goal of maximising the profit airlines derive from the use of a slot[7], which is linked to the willingness to pay for the slot by the airline.

A market mechanism with prices for slots would achieve this requirement, as long as the price reflects the willingness to pay for the slot. There comes in the problem of the revelation of the value of the slot for the airline, problem which could be solved, as we shall see later, by an auction mechanism.

In reality, the social benefits may not be maximised when profits are maximum, for different reasons: there can be conditions of limited competition, when an airline on a market has some market power, and uses that situation to raise prices, resulting in a decrease in social welfare. The allocation system chosen should therefore address this problem by preventing the building of market power.

Another potential problem is that airlines do not take into account the benefits for society of serving for example one regional market when demand does not reflect the importance for the economy of that particular market (there are external benefits not reflected in the demand on the route). This can lead to adaptations in order to take those external effect into account.

Finally, there is an equilibrium to find between the adaptability of the system to changes in demand or market conditions, and a stability necessary to the good functioning (return on capital) and development (investment incentives) of the airlines. With respect to stability, the established airlines currently favour the "grandfather right" system, which gives them a large degree of certainty over the future holding of slots. They may therefore be reluctant to adopt a new system whatever its qualities. We shall come back to the point of acceptability of a new system in the concluding section.

3.1 Advantages of selling slot utilisation licences

The European procedure for assigning slots on saturated airports is characterised by the fact that it is free of charge. Among the disadvantages of this procedure, the most obvious is the disproportion between the demand for slots and the slots that are actually available. Because of the information asymmetry between the authorities in charge of assigning slots and the airlines, it is difficult to assess which airlines will use the slots in the best manner as far as society is concerned.

Furthermore, due to the complexity of the problem, any administrative-type procedure is likely to lead to an inefficient situation in which certain slots are not allocated to airlines which are capable of valorising the situation.

A solution could therefore consist in selling a temporary licence to use slots. The most basic way of doing this consists in setting a price (possibly variable, depending on the time of day of the slot) whilst retaining the current procedure. Initially, this would reduce the demand for slots and consequently the risk of mistakenly attributing slots to companies which do not valorise them as much as others would. But this solution, which is the easiest to implement,

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[7] not taking payment for slots into accounts

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only partially solves the problem of asymmetrical information[8], and it does not solve the problem of entry barriers.

Economists tend to prefer the auctioning solution, which has the advantage (when well designed) of revealing private information held by airlines and favouring the possible entry of new airlines on airports. With this in mind, the objective is not to generate funds but to use the information based on how much an airline is prepared to pay as an indicator of the profits it expects to draw from operating that slot[9]. In this context, an auction would aim to assign a slot to an airline which considers that it can obtain the highest profit in exchange for a part of that profit.

We will also see that it is perfectly possible to design the auction in such a way that it takes into account factors that could appear to be important from a social point of view, but which would have no effect on the profits of the airlines or that they would not take into account. It is possible for example to reserve slots for regional services as it is done today.

However, the results can be catastrophic if the auction is not properly designed. And in the present case, there are so many assets to be allocated, and those assets have such high synergy, that we can expect a traditional auction to generate a number of perverse effects.

But to discuss auctioning a large quantity of assets without defining the rules of the auction is not particularly significant, because the designer of the auction has a very large number of parameters that can be adjusted and fine-tuned, all with very different effects.

As far as putting slots up for sale is concerned, we insist on the fact that there are systems which can considerably improve the efficiency of allocation. Even if we do not set up an auction system, which can be a complex matter, we could at least set up a variable price system without taking any risks, based on the time of day and on the estimated demand for slots at that time of day[10].

3.2 Market mechanisms and the survival of "reasonably" sound companies

The UMTS auctions that have been held in some countries are sometimes criticised for having played an important part in the financial ruin of a number of mobile telephone operators. Agreed, certain companies made astronomical bids in order to obtain a UMTS licence, but this is only the consequence of (now apparently) unreasonably optimistic forecasts made by those companies concerning the future of the sector. Those forecasts were furthermore expressed in the form of an incredible wave of acquisitions at considerably overvalued prices: Even if the auctions had not taken place, the situation would not have been

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[8] According to economic theory, in order to solve the problem of risking an attribution of slots to the "wrong" airlines, it would be necessary to find the prices for which demand equals supply, but this is impossible due to the very existence of asymmetrical information. And if we attempt to assess those prices in an aggressive manner, by trying to come close to the estimated limit prices, there is a risk that some of the slots - specifically the most sought-after - might not be attributed to anyone.

[9] In reality, the objective is not to maximise the profits of airlines, but rather the social surplus, defined as the difference between what consumers would be prepared to pay for a service and the costs induced by the production of that service. But we can consider, in a competitive situation, that if an airline thinks it will make large profits by using a slot, this fact indicates high demand and low costs.

[10] If we want to avoid taking risks, this system could be set up progressively, changing the prices cautiously over a period of about ten years, for example.

very different. In the context of air transport, which has a longer history than new information technologies, one can expect a little more moderation on behalf of airlines.

The fact that market mechanisms enable governments to raise funds generates criticism towards those mechanisms. However, it is necessary to raise revenues in order to achieve efficiency, since the revenues raised are the indication of the market value associated with the asset.

Nonetheless, the sale of slots creates a new cost item in a sector which is not in particularly good health. We can nevertheless establish certain measures which aim to reduce the impact of these costs.

First of all, the auction price or selling price can be based on the amount that the airlines are prepared to pay each month - for example - to obtain a slot. It is also possible to index the payment determined by the auctioning process on the level of activity of the sector, or on other indicators.

Finally, the income generated by the auctions can be used for the benefit of the airlines themselves. For example, the money could be used to finance an insurance fund[11]. But it is important that any support provided to an airline as a result of the collected funds should be as unrelated as possible to the amounts actually paid by that airline, in order to avoid distorting the bids made by the airline during the auction.

4 - Auctioning slot utilisation licences

In this section, we will present an auctioning system which theoretically enables an efficient situation to be reached, and which has certain very interesting characteristics. We also propose a few possible changes to this system, that we consider viable and interesting.

4.1 Choosing an auction mechanism

As regards auctions, several mechanisms can be designed, with different properties. Concerning slots, there are specific issues to be addressed by the auction mechanism chosen. We believe that the most important of theses issues is the aggregation problem: a specific combination of slots has more value for an airline than the sum of the individual values of slots. This is true between airports (we shall come back to this point later on), but also inside an airport: the hub and spoke organisation of networks, with arrival and departures concentrated in time, makes it important for an airline to have certain sets of synergetic slots.

With simple auctions, where assets are auctioned separately, airlines may fail to obtain all the slots they need and may end up with an inefficient allocation (from the point of view of their operation).

In order to reduce, or solve the aggregation problems, two main designs can be used: the first one is a simultaneous, multiple rounds auction (SMRA). The Federal Communication Commission (FCC) has used it for the spectrum auctions in the USA, with reasonable success. Basically, it allows firms to bid on individual assets, the auctions are held simultaneously for

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[11] This possibility is mentioned for the purpose of information: In the long run, the question of using the funds collected by the auction is actually a political choice, and it is not up to us to give our opinion.

all assets, and repeated as long as necessary so that nobody wants to change its bid. Assets are only allocated at this point.

DotEcon, in its January 2001 report [7], proposes a SMRA for the airport slots allocation, relatively close to the FCC procedure.

This mechanism alleviates the aggregation problem, but does not solve it entirely, because auctions are simultaneous but still separate. Bidders can not bid on bundles of slots and therefore may still face some aggregation problems.

Another way of solving this problem is the use of combinatorial or "package" bidding where bidders can bid on multiple bundles of slots. They obtain a whole package or nothing. This is what the FCC is currently experimenting with. By enabling bidders to bid on packages, this kind of mechanism eliminates the aggregation problem entirely.

Since we feel that the aggregation problem is an important issue with the slot allocation, we shall turn to a combinatorial bidding procedure, although this kind of auction is more difficult to implement.

4.2 An efficient mechanism: Vickrey-Clarke-Groves auctions

4.2.1 Definition

Among the mechanisms invented by economists to allocate rare assets, the Vickrey-Clarke-Groves mechanism ([24], [3], [8]) has a remarkable property: Whatever the strategies of the other buyers, the optimum strategy of any given buyer consists in bidding, without lying, the maximum value that he/she would be ready to pay for any bundle of assets.

To obtain this result, it is simply necessary for each buyer to have a reliable knowledge of the value that the auctioned asset or combination of assets will have for him/her if ever he/she were to obtain them. [12].

The Vickrey-Clarke-Groves mechanism allows for combinatorial bids: Bidders can submit bids for multiple combination of assets rather than just individual assets.

This mechanism operates as follows: Each player is asked to bid the maximum value that he/she would be prepared to pay in order to see each of the "states" of nature implemented (here, the state of nature represents the allocation of the auction: an identification of all the assets that each buyer obtains). The assets are then distributed according to the optimum allocation: This is determined by maximising, out of all the possible allocations, the sum of the values of the bundles assigned to the buyers on the basis of their bids. Finally, each buyer pays the seller the difference between the sum of the values of the allocation that would have been optimum if he/she had not taken part in the mechanism, and the sum of the values of the effective allocation for the other buyers (each buyer pays the seller what he/she costs the others - in terms of optimum allocation value - by taking part in the auction). For further details concerning this mechanism, the reader can refer to the book by V. Krishna [9].

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[12] Other theoretical contexts lead to different results, but in practice one can consider that only a VCG mechanism would have good properties in terms of efficiency of the allocation for the slot allocation problem.

4.2.2 Illustration

As an illustration, imagine that 3 assets A, B and C are up for sale, and that 4 potential buyers are ready to buy them at the following prices:

	A1	A2	A3	A4
A only	2	5	4	3
B only	3	1	3	3
C only	6	3	2	4
A and B	8	6	10	8
A and C	8	9	7	7
B and C	10	4	10	8
A and B and C	14	13	14	12

With a Groves mechanism, buyer A3 obtains assets A and B and buyer A1 obtains asset C - which maximises the value of the assets obtained by the buyers, 16 in this case).

To determine how much buyer A3 must pay, it is necessary to observe what the maximum value of the assets obtained by the buyers would be if A3 didn't take part. In this case, buyer A1 would obtain B and C, and buyer A2 would obtain A, making a total value of 15. In the end, A3 must pay 15 - 6 (where 6 is the value of the assets obtained by the other buyers - A1 in this case - when A3 takes part), i.e. 9.

To determine how much buyer A1 must pay, it is necessary to observe what the maximum value of the assets obtained by the buyers would be if A1 didn't take part. In this case, buyer A3 would obtain B and C, and buyer A2 would obtain A, making a total value of 15. In the end, A3 must pay 15 - 10 (where 10 is the value of the assets obtained by the other buyers - A3 in this case - when A1 takes part), i.e. 5.

Another illustration: for auctions concerning a single asset, the highest bid wins the asset, and in this case the buyer pays the second highest bid.

4.2.3 Properties

This mechanism has two very interesting properties. The first has already been mentioned: Whatever the bids made by the other buyers, every buyer stands the best chance if he/she bids his/her true values for each bundle of assets, and this implies that the allocation is efficient. This is a classic result so we will not provide any further demonstration.

Furthermore, it is possible to add distribution constraints to this mechanism, without losing the previous property. So if we decide for example that at least 70 % of the slots must be attributed to European airlines, we retain the property according to which airlines are well advised to make bids which are equal to their true values, provided that the payment rule is adapted so that payment is calculated on the basis of the optimum allocation under this constraint[13].

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[13] Technical comment concerning the payment rule in VCG mechanisms with allocation constraints: To calculate the payments, it is necessary to determine, for each buyer who obtains slots, what the optimum allocation would be, under the constraints, if that buyer did not take part in the auction. This could pose problems: For example, if the allocation constraint is that at least 4 buyers must obtain 4000 slots each, then if only 4 buyers take part in the

4.3 The combinatorial explosion problem, and how to restrain it

In practice, if slots are defined as they are today, it is not possible to set up this type of mechanism for selling slots because the number of combinations of assets increases exponentially with the number of assets put up for sale (2^n possible combinations if n assets are put up for sale). The real problem is not, in fact, the number of bids that the buyers would have to place: After all, one could easily leave it up to the airlines to decide the level of complexity of their bids, which would obviously not cover all the states of nature. The problem is above all connected with the calculation of the optimum allocation and of the payments, which becomes problematic as soon as the number of assets up for sale becomes excessive.

Tuomas Sandholm ([22], [23]) has been working on this problem for a few years: He has already designed an algorithm to calculate the optimum allocation and the corresponding payments as quickly as possible. We can currently estimate that it is possible to implement a VCG type mechanism for as long as the number of assets to be allocated does not exceed a few hundred[14].

We shall see that by redefining the slot, we can limit the number of assets significantly, without loosing flexibility in the bids

4.3.1 Definition of the asset to auction

The slot is the right to use airport capacity, and can thus be defined with this in mind. So far, the slot is defined as "...the scheduled time of arrival or departure...", and the sum of slots in a day matches capacity.

From an operational point of view, there is a 15-minute time window corresponding to the slot time, during which the airline is supposed to leave or arrive at its stand.

From an auctioning point of view, things can be seen with the same perspective, and the asset could be defined as "the scheduled time of arrival or departure, within a specified time window". Within a time window, there would be many slots, but they would all be the same from an auctioning point of view. This reduces considerably the number of assets to be auctioned, even with only a 15-minute time window. Furthermore, this is coherent with the operational constraints in an airport, and would not change fundamentally the current situation from the point of view of the airline operations.

However, this would not be sufficient to reduce the number of slots to the level necessary for solving the optimisation problem.

For example, let us take an airport operating 16 hours a day, with 100 takeoffs or landing a day. This amounts to 584 000 slots per year. By defining a 15-minute time window,

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auction it will not be possible to determine what the optimum allocation would be without one of the buyers, because there would only be 3 buyers left. To solve this problem, we can consider that there are also virtual buyers (as many as necessary) who assign a value of 0 to each bundle of slots.
With this payment rule, the best interest of the "real" buyers is still to bid their true values.
[14] He has also developed a logical language which enables buyers to describe their bids using a program, which means that it is not necessary to explicitly define the list of all bids.

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one comes to a number of assets of 23 360. If we sell 10 to 20 % of seasonal slots each season, this amount to a number of assets between 1 168 and 2 336.

We may still have too many assets to calculate the optimal allocation, and we need therefore to envision some additional methods, in order to reduce the number of assets.

The following are a few examples of methods which can be used to adapt a VCG mechanism so that the number of calculations involved can be completed in a reasonable amount of time, but they have a cost in terms of efficiency and we point out some of the disadvantages of these adaptations.

4.3.2 Auction a few hundred predefined groups of slots

The first possibility consists in grouping the slots into coherent sets of slots, in such a way as to obtain a few hundred groups[15] at the most. This grouping must be carried out in such a way that the groups are coherent in terms of synergy between the slots they contain (every opportunity to use historical data should be taken, when defining the groups). After proceeding in this manner to reduce the number of assets up for sale, they can be sold using a VCG mechanism.

The most obvious grouping of slots, is the grouping of slots throughout the season. We would obtain a slot for a time window specific to a day during the whole season.

This procedure is obviously not perfect in the sense that, although the airlines are always well advised to bid their true values for the various groups of slots, the optimum reached is nevertheless an optimum under constraint: all the slots in a given group are allocated to the same airline. However, since most airlines operate on a regular basis throughout the season, this would not be a problem, except for part season operators (charters). This can be dealt with by the existence of a second market which could enable these inefficiencies to be corrected[16] (provided that the assets sold are time-limited operating licences - and this is an essential point).

Illustration: We come back to our preceding example (584 000 slots), and group slots for a season. Without using time windows, we find a number of slots of 11 230. Auctioning between 10 to 20 % of slots each season, We find between 1 123 and 2 246 groups. Adding time windows enables to reach a level of complexity low enough to solve the optimisation problem in a reasonable time.

4.3.2 Iterate several auctioning rounds, limiting the number of bids by each airline at each round

Another possibility would be to hold several rounds of auctioning. At the end of each round, the allocation would be calculated using a VCG mechanism and the results (and possibly the bids submitted) would be announced to the airlines[17]. The airlines could then

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[15] We shall call « groups » the sets predefined by the auction organiser. The sets chosen by the bidders we call « bundles ». In a combinatorial auction with predefined groups of slots, bidder can bid on bundles of groups of slots

[16] One could also provide for the individual sale, in parallel, of some slots for non-regular flights.

[17] Milgrom et Weber [17] suggest that it would be interesting - in terms of efficiency and even of income generated by the auction - to give the buyers as much information as possible concerning the bids made by their

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make new bids during the next round, at the end of which the allocation would be recalculated on the basis of the bids made during all the rounds since the beginning of the auction. The idea would then be to encourage airlines to integrate the history of bids already made into their calculations, in order to avoid making bids which would not enable them to obtain slots, with the objective of limiting the calculations that need to be processed. With this in mind, it would be better if the airlines started by making bids, from the outset (i.e. the first rounds), for isolated slots or for small groups of slots[18]. Conversely, several individual bids for slots would immediately make it useless for anyone to bid for the complete bundle at a lower price than the sum of all the individual bids).

One major difficulty in designing iterative auctions is connected with the design of the rules for keeping the auction active or closing it. In other words, under what conditions does the auction end, and under what conditions does the buyer have the right to continue making further bids? The objective, here, is to limit any wait-and-see strategies on behalf of buyers, so that the auction closes after a "reasonable" time[19]. As an example, during auctions held by FCC to sell licences for using the Hertzian spectrum, the buyers were given a limit on the number of bids they could make at each round. This limit was determined on the basis of the number of bids they had made during previous rounds: A buyer who makes very few bids during a given round therefore loses the possibility of making a large number of bids during subsequent rounds. Obviously, for this to make any sense, the buyers must be prevented from making bids which are purely symbolic. (For a detailed analysis of the solutions and results concerning the auctioning of the Hertzian spectrum, refer to [4], [5], [12], [13], [15], [16]). We could use this type of rule here, possibly with an additional obligation to only make bids for individual slots (or small bundles) during the first rounds.

4.3.3 Limit the form of the bids that can be made by airlines

A final possibility, which enables the allocation calculations to be simplified considerably, consists in limiting the form of the bids that the airlines can submit. For

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rivals. In the case where the values of the various buyers are affiliated, i.e. the same case in which the VCG mechanism no longer necessarily yields the optimum allocation, the phenomenon observed can sometimes turn put to be what is known as the Winner's Curse: the one who wins an asset is the one who had the highest estimation of the value of that asset. This results in the fact that his/her estimation is biased, and it is likely to have been overestimated. Bearing this phenomenon in mind, buyers tend to adopt more prudent strategies which can cause the auction to yield less income, and the allocation to be inefficient. By running an auction in several rounds, between which the bids made by the buyers are made public, the buyers may be able to refine their estimation of the value of the assets and thus reduce the winner's curse.

Conversely, this reinforces the risk of collusion between airlines. Although it is true that collusion reduces income, it does not normally reduce the efficiency of the allocation, and our principal quest is the latter.

The issue as to whether the bids or only the results of each round should be made public is a complex one, and we shall not enter into a discussion on that subject here.

[18] whatever the amount of a bid made by a buyer for a bundle, another buyer could hope to obtain a part of that bundle even by making a very low bid, if a third buyer happened to make a high bid for the other part of the bundle

[19] This type of auction would then similar to the RAD mechanism designed by Kwasnica et al. ([10]).
The differences between the two are that, in this case, the mechanism makes buyers who win bundles pay the exact price that they bid for those bundles, and it does not limit the buyers' bids to individual assets during the initial rounds. Experiments carried out by these authors tend to show that this type of mechanism can have interesting properties in terms of efficiency.

example, if 30,000 slots are up for sale, and if one considers that an efficient allocation consists in allowing 4 airlines to hold coherent bundles of at least 4000 slots, it is possible to simply authorise the airlines to make bids[20] concerning (exactly) 4000 slots, 1000 slots or a single slot. The optimum allocation would, in this case, be determined under the constraint that at least four different airlines would obtain the bundles of 4000 slots they had bid for.

Conversely, with this system, it is not necessarily in the airlines' best interest to make "honest" bids which correspond to the values that they actually assign to the slots or bundles of slots. This is because there will be complementarities between slots that cannot be declared as belonging to the same given bundle of 1000 or 4000 slots. The airlines' strategy will therefore have to take into account the existence of these complementarities between assets which have not been requested in the same bundle, and the amounts bid for a bundle will no longer correspond solely to the value assigned to the bundle by the airline. Under these conditions, it is apparently no longer of any interest to adopt the VCG payment rule. It would no doubt be more pertinent to hold simpler auctions, similar to those held for the Hertzian spectrum in the United States (several rounds, and the sum of the amounts bid is maximised in order to decide on the optimum allocation. Each winner pays the exact amount of the bid he/she made), whilst retaining the possibility of making bids for bundles of 1000 or 4000 slots.

This possibility is therefore of less interest than the ones presented before, and we shall not take it into account in the final auction mechanism we detail in the next section.

5 - A proposed auctioning system

5.1 Description of the auction

Considering the advantages and disadvantages that we have discussed, we feel that the following mechanism could provide some interesting results.

The assets for sale are defined as licences to operate slots for a period of n years (n being between 5 to 10). Every year, $(100/n)$ % of the slots are put up for sale (10 to 20 %, corresponding to the duration chosen). After the auction, the airlines are entitled to sell their licences.

On each airport, the slots are grouped by the auction organiser into a certain number of groups which appear to be coherent from a historical point of view (the most probable coherent grouping being seasonal grouping), and time windows are defined (in such a way that there are only a few hundred groups of slots on each airport).

Then, iterated VCG (open) auctions are held on all the saturated airports, possibly with distribution constraints (for example: at least 4 different airlines must obtain more than a certain quantity of slots[21], or at least a certain percentage of slots is distributed to newcomers on the airport). The bids of the previous rounds are sustained during subsequent rounds. A rule for continuing the auction and a rule for closing it (similar to those used for auctioning the

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[20] As many as they wish.

[21] Which provides a form of insurance against excessive concentration.

Hertzian spectrum in the United States) are set up, and the bids concerning the first rounds of the auctions can only apply to individual slots.

Payments are determined on the basis of a monthly amount to be paid, calculated from the bids made by the airlines, using the rule of payment of a VCG mechanism with constraints. These payments are weighted according to the air transport activity level, on the basis of a rule announced at the beginning of the auction.

Some of the slots might not be auctioned, in order to be able to allocate them using other criteria. For example the government could keep slots for specific routes, as is already done currently.

After the auction a secondary market would be set up, ensuring efficient reallocation throughout the season. Since the organiser of the auction had to group the slots into groups of seasonal slots, the secondary market would enable airlines to obtain part season slots. Care should be taken as to the design of this market, in order to ensure that no building of dominant position could happen, as was the case on the US market for domestic slots.

5.2 Interaction between airports

For the time being, we have only discussed the problem of allocating slots within a single airport. There is obviously complementarity between the slots of the same airport, but the complementarity is even greater between certain slots of different airports. This is because, if an airline wants to set up a flight between two saturated airports, it will need to obtain a slot at each airport at compatible times. In theory, the ideal solution would be to hold a single global VCG auction, covering the slots of all saturated airports. But this would not be possible, if only for technical reasons concerning the combinatorial explosion. There is nevertheless still the possibility of holding separate auctions on each airport.

How should these auctions be held? If they are held sequentially, the airlines will be faced with one of the major problems of separately auctioning interdependent assets: the problem of aggregation risk.

This is because the airlines will initially do everything they can to obtain slots on one airport, without knowing whether or not they will succeed in obtaining the corresponding slots on other airports. In this situation, the strategies used by airlines become very complicated. The random factors that face the airlines are considerable, and it will probably be hard to obtain a coherent set of slots from one airport to the other.

From our point of view, it would be preferable to hold these auctions simultaneously, in several rounds, so that the airlines can adjust their bids on one airport based on the results obtained on the other airports[22]. It would require a European co-ordination.

It is not clear whether a single airport (or country) could find advantages in implementing a market mechanism alone, because of the complementarity problem, but also for another reason, the possible distortion of competition between European airlines.

An isolated auction could indeed disadvantage the national airline hubbing at this airport, in its competition with the other national "hub" airlines. This could prove politically unacceptable, as it would upset a fragile competition equilibrium. Solutions could however be

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[22] For further details on this subject, refer to the debates on the form to be given to auctions of the Hertzian spectrum in the United States, [4], [5], [12], [13], [15], [16]

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implemented to alleviate this problem. One would be to run the auction under the constraint that national airlines (or all airlines using the airport) eventually obtain the same proportion of slots as they have today. Another would be to compensate for the extra cost to the airlines using that airport (through an airport fee decrease for example[23]). Both systems could be combined and could be used as a temporary mechanism, in order to wait for the generalisation of the market mechanism.

Still, ideally, we think that a new system should have to be Europe-wide.

5.3 Strategic links

As we are concerned with efficiency, one of the major risks is that no airlines succeed in obtaining the slots they require in order to set up an important link between two saturated airports (or that the number of links set up is too small) or one saturated airport and a regional one (regional service).

We can nevertheless adapt the preceding mechanism in order to protect the system from this risk. For example, if we are worried that there might be an insufficient number of links between Paris and Madrid, and we want to ensure that the slots distributed in a given year for Paris-CDG and Madrid are used to provide at least one return link between these two cities every day, the mechanism can be modified in two ways:

The first possibility is to allow the airlines to designate some of the slots in the bundles they are bidding for as "Paris-Madrid" or "Madrid-Paris" in the auctions concerning Paris-CDG and Madrid. The allocation of the auctions on each airport is then determined using the constraint that at least one slot per day must be designated "Paris-Madrid" and another must be designated "Madrid-Paris". This constraint can make it easier for airlines to obtain the slots concerned. In exchange, the licence to use these slots must be used for the corresponding link; otherwise the airline will be given a heavy fine or will have its licence withdrawn (even if it is subsequently sold to another airline).

Having said this, the adaptation described above does not entirely solve the problem because it may still be difficult for an airline to obtain both the slots corresponding to a given flight in the case of two saturated airports. Conversely, this procedure enables airlines to determine at what time of day the flights will take place, based on their information concerning demand.

The second possibility consists in arbitrarily grouping together, in a single groups, two slots which enable a Paris-Madrid link to be set up (one on each airport), and putting this "Paris-Madrid" group up for sale either in the Paris-Roissy auction, or in the Madrid auction. Here again, the corresponding licences would come with an obligation to use the slots for the "Paris-Madrid" link, otherwise there would be a heavy fine or the licences would be withdrawn.

This adaptation solves the problem of bringing together complementary slots on both airports. Conversely, it is less flexible because the time of day is imposed on the airlines.

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[23] As we already emphasised, this decrease in airport fees should be independent from the revenue generated by the auction, in order not to distort the bidders' strategies.

It is somehow close to what is done currently, with the "grandfather rights" system, where governments can reserve a proportion of the slots for regional services.

It should nevertheless be noted that both these adaptations could have adverse effects on the competition factor. This is because the allocation of a route-related licence to an airline makes it credible for that airline to operate that link and this might restrict any incentive that other airlines have to compete on that route. For this reason, we recommend that these adaptations be used sparingly (to guarantee a minimum number of essential links, without covering the full quota of passenger demand for the routes concerned).

5.4 Market power

Since one of the primary goals of the slot allocation is to promote competition, the mechanism chosen should be capable of addressing the issue of market power. Rules should be devised that prevent too much concentration on routes, even if no direct relation systematically exists between concentration and market power on routes.

To this effect, constraints could be placed on the concentration level authorised overall or on a route, and integrated in the auction mechanism, or dealt with afterwards, on the secondary market. Such constraints should also be taken into account in the secondary market. It is beyond the scope of this paper to develop this subject in a more extended way, as it is a matter for competition legislation.

Conclusion

After reviewing the shortcomings of the current slot allocation procedure in Europe, we have proposed a market mechanism, based on temporary utilisation licences, allocated through an iterated combinatorial auction.

It is one among many possible (auction) mechanisms, but we believe it has interesting properties in terms of efficiency and flexibility. We saw that adding constraints to the allocation is always possible without distorting the optimal strategies of the bidders, which is to announce their true values for each bundle of assets, implying that an efficient allocation is obtained. We also saw that should we need to reduce the computational complexity induced by the mechanism, it is preferable to predefine groups of slots rather than limit the form of the bids.

Several parameters of the mechanisms remain to be specified, like the duration of the licence, or the time window defining the slot, but overall, this mechanism should allow for a much more efficient use of the slots than today.

As we pointed out, ideally, such a mechanism should be implemented at the European level, in order not to distort competition between European airlines, and so that airlines can constitute coherent sets of slots between congested airports.

A point we did not develop in the paper but needs careful consideration from a practical point of view is the acceptability of this system. As mentioned, any new system would find hostility on the part of the established airlines, since it would imply taking from them what

they get nowadays for free, and consider to be part of their assets. Other airlines would be more favourable to a new system, if it enables them to gain access to so far unreachable airports.

Among new systems, one that solves the aggregation problem (the problem for an airline of not obtaining a coherent set of slots) like the one we proposed, is likely to be seen more favourably than one that does not address this problem.

Overall, the system of air transportation prevailing in Europe today is still one of national airlines. A new slot allocation mechanism would allow for (gradual) changes in that system, which may or may not seem acceptable from a political point of view, considering the social implications (what consumers could gain from more competition could be lost by workers, for example). The desirability of having a national airline is however a political issue, which we can only mention but not solve.

We are not claiming that our proposal is final, we are simply trying to contribute to a debate on the feasibility, the risks and the interest of such a procedure. We are in the process of designing a computer program to simulate competition between airlines, in order to launch an experimental economic program to compare the consequences of this mechanism with those of different modes of allocation.

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A Study on the development of service quality index for Incheon International Airport

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Key word : service quality/ marketing/ MCJ/ importance measurement

<Abstract>

The main purpose of this study is located at developing Ominibus Monitors System(OMS) for internal management, which will enable to establish standards, finding out matters to be improved, and appreciation for its treatment in a systematic way. It is through developing subjective or objective estimation tool with use of importance, perceived level, and complex index at international airport by each principal service items,

The direction of this study came towards for the purpose of developing a metric analysis tool, utilizing the Quantitative Second Data, Analysing Perceived Data through airport user surveys, systemizing the data collection-input-analysis process, making data image according to graph of results, planning Service Encounter and endowing control attribution, and ensuring competitiveness at the minimal international standards .

It is much important to set up a pre-investigation plan on the base of existent foreign literature and actual inspection to international airport. Two tasks have been executed together on the base of this pre-investigation; one is developing subjective estimation standards for departing party, entering party, and airport residence and the other is developing objective standards as complementary methods

The study has processed for the purpose of monitoring services at airports regularly and irregularly through developing software system for operating standards after ensuring credibility and feasibility of estimation standards with substantial and statistical way.

1. The purpose of study

The main purpose of this study is located at developing Ominibus Monitors System(OMS) for internal management, which will enable to establish standards, finding out matters to be improved, and appreciation for its treatment in a systematic way. It is through developing subjective or objective estimation tool with use of

importance, perceived level, and complex index at international airport by each principal service items

2. Content consist
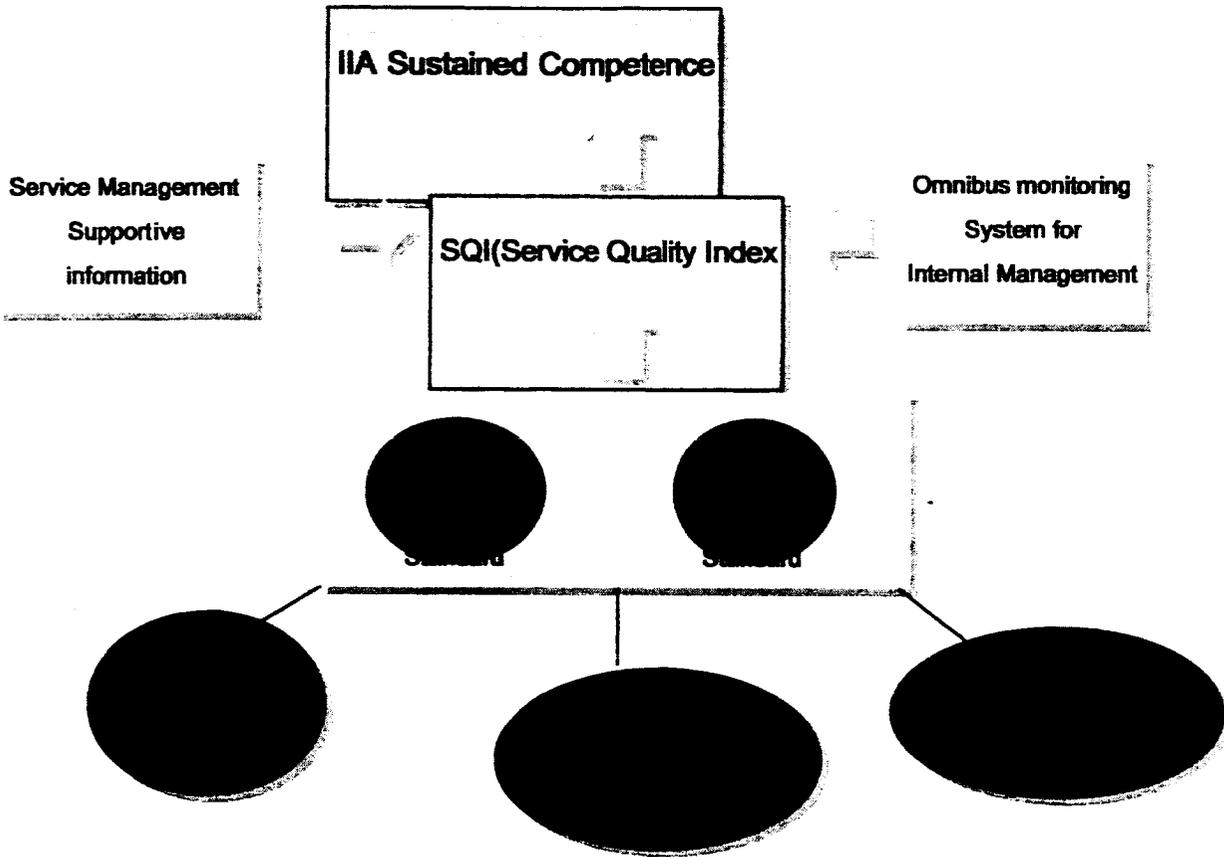
3. Procedure

In accomplishing this research, it is much important to establish and execute pre-investigation plan on a basis of existing foreign literature and the actual investigation of Incheon International Airport. With this result the pre-investigation, it is possible to develop subjective measurement scale of those embarking, those disembarking and the airport residual employees as well as development of objectivity index as a complementary method.

4. Composition of measurement index

1) The number of passenger related field(airport/terminal ground access) : 35

   (1) The number of common items between ACI and IATA: 23

   (2) The number of service categories used by which more than 18(25%) of ACI member airports : 5

   (3) The number of service categories used by which more than 12(20%) of ACI member airports : 2

   (4) The number of service categories used by which more than 3 of ACI member airports but excepted from the measurement adopted above: 4

   (5) SATS : 1

2) The number of important items in other field : 28

   (1) The number of items which is excepted from the measurement adopted above but used by more than 5 of ACI member airports

3) The number of airlines-related items : 10

   (1) The number of common item between ACI and SATS : 8

   (2) SATS : 2

5. Inducement of Weight Production Function

1) The fundamental concept of MCJ

In evaluating the service quality perceived by consumers or customers , most of research adopts frequency analysis or descriptive statistical methods through the qualitative data collected by surveys. But it is not pertinent to use this qualitative data for quantitative analysis. For instance, 5 respondents answer back as 4.00 degree on the question of the level of importance of airport check-in service. It, however, cannot said all of those 5 respondents evaluated with the same level of

importance of check-in services. This comes from each person think each different evaluating categories. These problems require a certain process to transform the qualitative data into quantitative one. From this research which study on the evaluation frame for airport service quality, the Method of Categorical Judgment(MCJ) of a methodology of psychology field was used to transform the qualitative data into quantitative one.

2) Benefit of MCJ (The Method of Categorical Judgment)

(1) quantifying qualitative data as quantitative one.

(2) quantifying probability of the characteristics of various airport users

(3) quantifying qualitative weight according to the characteristics of airport users

(4) Classifying the service standard of use

(5) Classifying to general user's characteristics

(6) Differentiation of importance by each service items

(7) Ability to composite a matrix of importance and satisfaction for operation

management purposes

3) MCJ Methodology

MCJ(The Method of Categorical Judgment: Bock, R.D., and Jones, L.V. *The measurement and Prediction of Judgment and Choice*. San Francisco, Holden-Day, 1968.) is a method to convert qualitative data to quantitative one in evaluating of airport service quality. The purpose of MCJ is lied in presuming a quality (parameters) which shows the characteristics related with the respondents' attitude to the series of stimulus by converting qualitative data to quantitative one

The measurement of response is made up using normal function. The average and dispersion of the stimulus, and it is possible to presume the boundary of categories

related with the qualitative measurement used from the responded data.

6. Implementing survey

1) Survey method

CLT method

2) Composition of survey target

(1) The number of total respondents : 204

(2) Departure passengers(95) : Domestic(52), Japanese(15), Chinese(13), Those come from English-spoken culture(15)

(3) Arriving Passengers(63) : Domestic(33), Japanese(10), Chinese(10), Those come from English-spoken culture(10)

(4) Airport residual employees(50) : airlines(20), shops(10), government officials(10), ground handlers(10)

3) Survey result satisfaction score(5 full score standards)

- Departure passengers : 3.72

- Arriving passengers : 3.62

4) Reliability

As a result of Cronbach-a test, most of them shows high reliability as above 0.8 (below* the examples of departure passengers are shown in table, and others omitted due to the fall short of paper space)

(1) Items of satisfaction of departure passengers

[Chart 1] The reliability of departure passengers' satisfaction

Categories of service	Alpha
FIDS	0.8513
Information desk/Telephone information	0.9456
Information guidance post	0.9234
Check-in service	0.9547
Security search	0.9346
Immigration	0.7847
Baggage trolley/porters	0.9362
Food/Restaurants/Bars	0.9467
Duty free shop/shop	0.8929
Departing lounges/waiting areas/Gate lounges	0.9433
Customs	0.9506
Transfer procedures	0.9483
Car	0.6486
Bus	0.9235
Taxi	0.8997
Parking	0.7381
Other services	0.8739

5) Weight by regression analysis

(1) The value of R^2 , t-value is not significant statistically

- The value of R^2 is appeared to be significant only in case of departure,

however, is not significant in case of arriving or airport residual employees
As for the ß-value , the number of independent variables which has significant t-value is
6 out of 17 departing variables; otherwise in case of arriving, all of 16 arriving variables
are not significant, and in case of airport residual employees, one variable is significant
among 27 variables.

(2) Occurrence of multi-collinearity because there are highly correlation
between independent variables. The Pearson product moment correlation value
independent variables are all significant within 10% consideration levels, therefore it is
not desirable that applying regression equation with these independent variables.

7. Comparison of Weight

1) Comparison of arithmetic average between MCJ and raw data

(Ex. Departure passengers)

When it performs relative comparison with converted % of the value of arithmetic average of raw data of importance evaluation, the gravity difference of importance by each item is too low. It can be seen on the difference of the arithmetic average value of raw data in measurement items. But in the comparison between items by MCJ methods adopted in this study, it definitely shows the differences.

[Chart 2] comparison between arithmetic average of raw data and MCJ

(Depature passenger)

Items of Service	MCJ			Arithmetic average		
	?	Converted value(10?)	%	Arithmetic average	Converted value10?)	%
Guidance post	0.969	10.00	9.25	4.677	10.00	6.45
Airport access road	0.386	7.75	7.17	4.560	9.75	6.29
Check-in service	0.366	7.67	7.10	4.559	9.75	6.29
Security Check	0.222	7.12	6.59	4.467	9.55	6.16
Bus	0.216	7.09	6.56	4.467	9.55	6.16
FIDS	0.205	7.05	6.52	4.527	9.68	6.24
Information desk/telephone desk	0.142	6.81	6.30	4.355	9.31	6.01
Connecting with other airline flights	0.141	6.80	6.30	4.352	9.30	6.00
Immigration/Passport	0.115	6.70	6.20	4.247	9.08	5.86
Taxi	-0.089	5.92	5.47	4.143	8.86	5.71
Departing lounge/waiting area/Gate lounge	-0.151	5.67	5.25	4.272	9.13	5.89
Transfer procedures	-0.159	5.64	5.22	4.250	9.09	5.86
Baggage trolleys	-0.165	5.62	5.20	4.194	8.97	5.78
Customs	-0.215	5.43	5.02	4.033	8.62	5.56
Car parking	-0.319	5.03	4.65	3.921	8.38	5.41
Duty-free shop/shop	-0.610	3.91	3.61	3.728	7.97	5.14
Food/Restaurant/Bars	-0.621	3.86	3.57	3.758	8.04	5.18
Tatal		108.07	100.00	72.509	155.02	100.00

2) Comparison MCJ with ß-value (departure passengers)

When producing the level of importance of items using regressive formula, it is
predicted to be a problem of multi-collinearity because the correlation between items is
forecasted to be much high according to the natural characteristics of this study. And
the analysis result show it had no significant by statistically. Nevertheless, in the MCJ
analysis, the all items passed goodness of fit. Here follows the comparison of them.

[Chart 3] Comparision MCJ and ß-value(departure passenger)

items	MCJ		Regression	
	μ	ranking	ß	ranking
Guidance post	0.969	1	0.061	10
Airport Access road	0.386	2	0.571	3
Check-in Service	0.366	3	0.409	4
Security check	0.222	4	-0.124	14
Bus	0.216	5	0.692	1
FIDS	0.205	6	0.188	6
Information desk/telephone information	0.142	7	0.026	11
Immigration/passport	0.115	8	0.092	7
Taxi	-0.089	9	0.543	2
Departing lounges/waiting area/Gate lounges	-0.151	10	-0.341	16
Customs	-0.215	11	-0.018	12
Transfer procedure	-0.159	12	-0.092	13
Baggage trolley	-0.165	13	0.085	8
Car parking	-0.319	14	-0.164	15
Duty-free shops/shops	-0.610	15	0.331	5
food/restaurants/bar	-0.621	16	0.068	9

8. The example of producing the amended value

1) Departing passenger

The scores of each service items can be achieved through multiplying the satisfaction level(5 full score standards) of each service items and the level of importance produced by MCJ value by the converted level of importance(%) to 100% ration of component. The final result was the scores of each service items. Setting 500 as full score standards , the total sum of them was 372.38 as pre-test results and it falls to 74.50% of total. The amended value of arriving passengers and airport residual employees can be achieved through the same way

. [Chart 4] Correction Value Output - departure passenger

items	Average level of satisfaction	Level of importance(%)	Corrected value
Guidance post	3.60	9.25	33.34
Airport Access road	3.93	7.17	28.20
Check- in Service	3.89	7.10	27.61
Security check	3.46	6.59	22.80
Bus	4.07	6.56	26.73
FIDS	3.54	6.52	23.11
Information desk/telephone information	3.60	6.30	22.71
Connection with other airline fight	3.75	6.30	23.66
Immigration/passport	3.49	6.20	21.68
Taxi	3.70	5.47	20.28
Departing lounges/waiting area/ Gate lounges	3.90	5.25	20.52
Transfer procedure	4.03	5.22	21.06
Baggage trolley	3.82	5.20	19.90
Customs	3.76	5.02	18.89
Car parking	3.57	4.65	16.62
Duty- free shops/shops	3.66	3.61	13.24
Café/Restaurant/Bar	3.40	3.57	12.14
Total		100.00	**372.48**

Note) 1. The level of importance(%) is weight reproduced by MCJ
2. The Corrected value is achieved through multiplying the average satisfaction level and MCJ level of importance(%)
3. Same process will be applied to arriving passengers and airport residual employees

9. Conclusion

Seen from above research result, the foregoing research should include that the airport service evaluation index to be developed with distinction the subjective field from objective field fundamentally and each service level target should be established and managed. Particularly, in case of subjective index, the hight persuasive result value can be found as a result of investigating the weight level of importance and applying it as more quantified through MCJ methods.

1) Classification of subjective area and objective area

2) Composition of index by existing literatures and opinions from experts

3) Distinction of departure passengers, arriving passengers, airport residual employees, objective index

4) Implementing substantiate market survey for development index

    (1) Composition of plural items and measurement of level of importance

    (2) Ensuring statistical reliability and reasonableness

5) Establishing target value by each index

6) Amending target value with consultation with concerned airport authority's department

<Appendix>

[Chart 5] composition of subjective and objective items to be measured

Service area	Detail items	
	subjective	Objective
FIDS/light board	· pertinent location of deployed · quick information	
Information desk	· familiarity with staff · expert of staff working · pertinent response to question	· waiting time telephone response
Guiding post	· optical perception · pertinent number of posts · expression	
Check-in service	· familiarity with staff · efficiency of staff working	· waiting time for check-in
Security check	· familiarity with staff · efficiency of staff working · feeling to security	· waiting and passing through time
immigration/ passport	· manner of staff working · waiting time for procedure	time taken waiting and passing through inspection · time taken for immigration procedures
Baggage delivery	· easiness for use of baggage trolley · service speed of baggage treating	· the time period between first baggage and last · waiting time for passenger baggage · exact classification of baggage
Baggage trolley/porter	· availability of carter · convenience of moving carter · pertinent fare for using porter	
food/restaurant/bar	· the quality level of food · cleanliness · level of price vs service · variety of kind of selection · courtesy of restaurant employee · waiting time/staff service efficiency/delivery time	

Duty-free shop/shop	· variety of selection type · price when considering the quality of product · courtesy of clerk · waiting time/staff service efficiency/ speed of service	
Departing lounges/waiting area/gate lounges	· seat confortability/cleanliness · seat availability	
Customs	· attitude and courtesy of custom officer · speedy progress of inspection	· waiting time
Other services	· delay measurement of flight · customer opinion proposal system · availability of public telephone/ · restroom · cleanness of terminal	· customer complainment handling · aircraft average rate of punctuality
Transfer	· connect convenience other flight · service efficiency of transfer counter · staff manner of transfer counter	· transfer time
Bus	· friendliness and attitude of bus driver · interval time	· punctuality of longhaul limousine
Taxi	friendliness and attitude of taxi driver · pick up a taxi	· taxi waiting time
Car	· road signpost/traffic signpost · disturbance expense level(including to fuel price, tollpay)	
Parking area	· ease of finding site · proximity to terminal building · fares	· The internal organs parking lot – terminal for shuttle bus waiting time · waiting time exit of parkinglot

	· availability of parkinglot · attitude of personnel working at parking	

Airport residual employees(subjective inquiry)	
Commoness	· attitude of airport corporation staff · construction staff attitude. the control against the chief mourner worker opinion proposal · airport expense efficiency · whole cleanness of terminal
Cargo	· whole cargo service · cargo equipment, warehouse/cargo facilities and land avalibility
Facilities	· the number of runway, apron, taxiway · apron and gate availability · airport's technical equipment availability · ground handling facilities availability

Security service	[terminal security]
	  · passenger baggage security check
	  · passenger soul cap hour control
	  · the travel document and the passport and contrast confirmation of onboard volume
	[airside security]
	  · the aviation side for luggage it searches
	  · luggage protection and escort
	  · luggage ID
	  · aircraft security checking
	[the freight and mail checking].
	  · the freight and the express dispatch freight it searches
	  · security control of the treasure and the diplomatic mailbag
	  · protection and escort of freight mail
	[generality]
	  · urgent request confrontation attitude
	  · Courtesy and the attitude which helps.
	  · human being the etiquette

Terminal service	· Departure gate control · boarding and the others guidance broadcasting clearness

	· control of the passenger where the help due to an advance request is necessary
	· passenger support from the luggage arrival area
	· lost article center service
	· the luggage tracking coordination which is controlled
	· human being the etiquette
	· courtesy and hep the attitude which it gives
Emigration passenger · Airport residual employee (common)	
· airport fine view satisfaction.	
· airport use general satisfaction	

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Leasing as a Source of Financing by Major US Airlines – Hidden Debt and its Changes Over Time

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Abstract

This paper updates prior research on aircraft leasing and contrasts the findings of current data with prior results. Usage of leases by air carriers is a means to lessen the impact of financial obligations from fleet purchases. The study revisits two previous studies, one in 1969 and one in 1991, which analyzed the incidence of leases by major air carriers. The current study updates these past studies to consider air carriers current usage of leases. Additionally, since operating leases are not reflected in the balance sheets of airlines, operating lease information was capitalized using a present value of future operating lease payments. Then, financial debt burden ratios were computed to determine the impact from the capitalization of lease information.

The usage of operating leases increased significantly from the first study to the 1991 study, and this trend continues. The incidence of leasing, the classification of leases as operating, and the percentage of operating leases to total fleet have all increased for the majority of the airlines reviewed. When operating lease data were capitalized, debt ratios weakened, providing further evidence of deterioration in the financial health of air carriers.

Keywords: Leasing, Capital Leases, Operating Leases, Air carriers, Debt

Introduction

The airline industry has suffered recent financial distress. September 11th, SARS, and the general economy have reduced air travel. UAL is currently operating under Chapter 11 bankruptcy, US Airways recently emerged from a Chapter 11 bankruptcy filing, and financial indicators for most air carriers are in a decline. This paper looks at one indicator of financial health - debt to equity ratios - and considers the impact of leasing upon the reported financial burden of the airlines. This paper revisits two studies, one in the early 1970s (Gritta, 1974) and the other in the 1990s (Gritta, Lippman, and Chow, 1994) that investigated the use of aircraft leasing to lessen the impact that financial obligations have upon financial ratios. This study updates the prior studies' data to determine the continuing financial impact from characterizing aircraft purchases as leases.

Reporting of Leasing on the Financial Statements

Prior to 1976, the impact of most leases was not reflected in the financial statements of air carriers. Then, lease accounting followed Accounting Principles Board (APB) No. 5, Reporting of Leases in Financial Statements of Lessee. This pronouncement required capitalization of a lease only when the lease created a material equity interest in the property, e.g. when the noncancelable lease was, in substance, a. purchase. Specific criteria outlined in APB No. 5 required lease capitalization when either the lease and renewal option term were greater than or equal to the useful economic life of the asset, or when a bargain purchase option was included in the lease. Firms were required to include footnote disclosure for lease commitments of material noncancelable leases (APB No. 5, 1964). In actuality, most leases were not recorded in the financial statements. Through structuring asset purchases as leases, firms could use leases as a means of off-balance sheet financing to avoid what many considered to be debt obligations. The non-recording of leases on the financial statements significantly affected the financial statements and ratios developed from them (Gritta, 1974; Nelson, 1963).

Currently, the reporting of leases on the financial statements is governed by Financial Accounting Standards Board (FASB) Statement of Financial Accounting Standards No. 13, Accounting for Leases. This statement, in effect since 1976, requires that firms classify leases as either operating or capital, dependent upon four criteria: the lease transfers ownership of the property to the lessee at the end of the lease term, the lease contains a bargain purchase option, the lease term is equal to 75% or more of the economic life of the leased asset, or the present value of the minimum lease payments at the beginning of the lease term equals or exceeds 90% of the fair value of the lease property (SFAS No. 13, 1976). If one of these conditions for capitalization is met, then the lease is characterized as a capital lease, and the leased asset and corresponding obligation are recorded on the balance sheet. If, instead, the lease is identified as an operating lease, then only the yearly lease payment is reflected as an expense on the income statement.

While the APB primarily considered material equity as the underlying motivation for capitalization of leases, the FASB considered whether the lease, in substance, transferred ownership risks and benefits. With the implementation of No. 13, it was hoped that firms' usage of off-balance sheet financing would diminish. However, since the criteria for capitalization include specified targets, lease terms can be structured to avoid capitalization, and some managers continued to classify as operating leases those leases which are, in substance, capital leases (Donegan and Sunder, 1989). When classified as operating leases, both assets and debt obligations are potentially understated.

Aircraft Leasing in the 1960s

The original lease study reviewed the large air carriers, now referred to as majors, and determined the effect from capitalizing lease obligations. Leases were identified as either operating or financial. Classification of leases as financial followed the classic definition as articulated by Vancil and Anthony (1963) who categorized leases as financial in nature if the lease term was approximately equal to the depreciable life of the airframe, if there were options to purchase and/or renew at the end of the initial term, if the aggregate rentals under the lease's initial term exceeded the then new purchase price of the aircraft, and if the leases were net leases.

The study found little ambiguity in the classification of aircraft leases, as the majority of the lease agreements were financial in nature. Only a few of the leases were categorized as operating (short term), and most of these leases met none of the financial lease criteria. But, regardless of whether a lease was identified as financial or operating, in practice most leased assets and their corresponding debt were not reflected on the balance sheet.

Since financial leases resemble, in substance, long-term debt finance, the original study determined the impact from constructive capitalization of financing lease data on total capital and debt ratios. It was assumed that cancelable operating leases did not have a significant impact upon the financial statements, so no capitalization of their data was deemed necessary. Data were obtained from 1969 filings with the Civil Aeronautics Board (CAB), which provided actual lease obligations. The study found that only 19% of the total fleet was leased, and of these only 13% were operating. The study reported that most leases were not reflected in the financial statements, and capitalization of lease information had a significant negative impact upon debt ratios, adding to the existing debt burdens of the companies.

Aircraft Leasing in the 1990s

The follow-up study used the carriers identified in the earlier study, and updated the data to consider lease usage in 1991. Subsequent to the original study, several carriers had ceased operations (Eastern and Braniff) or merged with other airlines (National, Western, and Northeast). The size of the sample for the follow-up study was increased by inclusion of new major carriers including Alaska Airlines, Southwest, US Air, and America West. Data were obtained from the financial statements as reported to the

Securities and Exchange Commission in 1991, since filings with lease information were no longer required by the CAB by that time.

The study found that the percentage of the fleet leased increased from 19% in the first study, to 54%, with 82% identified as operating, up from 13%. Clearly, a significant change in fleet financing had occurred, from straight debt to more leasing as a means of financing ownership, and the impact from the recording of these leases as operating leases resulted in a large understatement of financial debt burden ratios.

Aircraft Leasing in 2002

In this current study, we again considered the incidence and nature of leasing by the major carriers identified in past studies. The original study reviewed lease information for 11 airlines, and the updated study identified nine carriers with available lease information. Data for these airlines were similarly reviewed for the fiscal year ending 2002. Of the nine previously identified in 1991, two were operating under Chapter Eleven bankruptcy protection (UAL and US Airways) for the year 2002. TWA is privately held, and separate financial data are unavailable. Northwest, for which data previously were unavailable for the second study although available in the original study, has available information for 2002.

Table I reports the number and percentage of leased aircraft by carrier in 2002. Information from the prior study is included for comparison. Percentage of planes leased varied from a low of 25.9% reported by Southwest Airlines, to a high of 93.0% for America West. This is contrasted with the rates found in the second study, which ranged from a low of 44.2% to only 81.2%. Alaska and American Airlines had a decrease in the percentage of planes leased, Delta was essentially unchanged, while the remainder had increases. Southwest Airlines, with the lowest percentage of planes leased in 2002, did not have data available for the 1991 study.

More critical than percentage of fleet leased is the percentage of leases identified as operating leases, which avoid balance sheet classification. Table I classifies the number of leases as operating or capitalized leases, and Table II identifies the percentage of leases categorized as operating or capital, with information from the prior study included for comparison. Consistent with the prior updated study, most leases are structured as operating leases, a significant difference from the original study when operating leases were only 13% of all leases. The percentage of leases classified as operating ranged from 80.1% to 99.2%; in the updated study the percentage ranged from 78.8% to 100%, so no material increase was noted for air carriers as a whole. Operating lease percentage increased greatest for US Airways and Continental.

Because the percentage of leasing changed, as had the mix of operating/capital classifications, we looked at the percentage of planes identified as operating to total planes in the fleet. This might better determine the company's usage of leasing as off-balance sheet financing. The results are listed in Table II. Operating leases as a percentage of the total fleet ranged from 24.0% to a high of 93.0%. In contrast, the prior

study ranged from 37.8% to 81.2%. While the current study's range included a lower percentage, this carrier, Southwest, did not have available information for the prior study. Southwest is currently the most financially healthy of the airlines, having shown a profit the last few years when other airlines have incurred significant losses. Only American showed a decline in the usage of operating leases for its fleet.

Operating leases are not reflected in the balance sheets of the airlines, although the yearly future obligations of the leases are disclosed in the footnotes to the financial statements. We estimated the impact of these obligations on the balance sheet, by determining the present value of the noncancelable operating lease payments in a manner consistent with the prior 1991 study.[1] The operating lease disclosures reported in the financial footnotes include the yearly obligation for the next five years, and then a total of the remaining obligations. We assumed that the last reported yearly amount would continue into the future, allowing us to estimate the remaining life of the lease payments. These were then discounted to the present year assuming an appropriate interest rate.[2] The present values of the lease obligations were then included with the recorded long-term debt to compute the adjusted long-term debt obligations for each airline. These computed values are disclosed in Table III along with the long-term liabilities and equity for each air carrier.

Table IV presents the ratios of the airlines based, first, upon the reported financial statements and then assuming lease capitalization. Although the debt burden for the airlines is already quite high without lease capitalization, capitalization of operating leases increased the reported levels of the debt burden, particularly for the Debt/Equity ratio. In essence, the frailty of the airlines industry becomes even more evident with the capitalization of the operating airlines.

Conclusion

The purpose of this paper was to update prior research on aircraft leasing and contrast the findings of current data with prior results. In 1969, weaker carriers tended to lease a higher percentage of their aircraft, and these leases tended to be classified as finance leases. These leases were not reflected on the balance sheets of the air carriers. By 1991, the incidence of leasing had significantly increased for all carriers and many of these leases were classified as operating leases. In 2002, the incidence of leasing, the classification of leases as operating, and operating leases as a percentage of total fleet usage have all increased for the majority of the airlines. Capitalization of operating lease obligation weakens the debt ratios, evidence of further deterioration in the financial health of the air carriers.

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[1] For some airlines the lease payments disclosed in the financial statements were detailed separately for aircraft leases, and ground and other equipment leases; other airlines included both of these together as one number. Since the majority of air carriers do not separate out the lease payments by type of asset, we capitalized all operating lease payments.

[2] The 1969 and 1991 study used a 10% discount rate, and for consistency we used 10% for the current study. Today, interest rates are considerably less than in the early 90s. A lower rate would increase the amount of the obligation. This study's reported impact upon the financial statements from capitalizing operating leases is understated.

The prior study argued for disclosure of specific air carrier lease data. Certainly, the need still exists today. Short of specific data, however, capitalization of operating lease data can be determined using various assumptions about maturity and implied interest in the lease. Capitalization is necessary to produce a more accurate picture of the obligations of the air carriers. With the current economic climate, capitalization of leases is imperative to provide a more representative indication of the air carriers' financial burden.

Table I
Leased Aircraft

Carrier	Total Fleet	Operating Leases	Capital Leases	Planes Leased	% Leased 2002	% Leased 1990 (Per prior study)
Alaska	102	45	3	48	47.1%	79.0%
American	819	281	70	421	42.9%	61.6%
America West	143	132	1	133	93.0%	81.2%
Continental	636	453	9	462	72.6%	68.6%
Delta	831	313	45	358	43.1%	44.2%
Northwest	575	233	18	251	43.7%	n/a
Southwest	375	90	7	97	25.9%	n/a
UAL	567	241	59	300	63.3%	45.5%
US Airways	413	252	0	252	52.3%	47.3%

Table II
Lease Classification Percentages

Carrier	2002 % Leases Operating	1990 % Leases Operating	2002 % Fleet Operating	1990 % Fleet Operating
Alaska	93.8%	n/a	44.1%	n/a
American	80.1%	78.8%	34.3%	48.5%
America West	99.2%	100.0%	93.0%	81.2%
Continental	98.1%	84.3%	71.2%	57.8%
Delta	87.4%	90.0%	35.7%	39.8%
Northwest	92.8%	n/a	40.5%	n/a
Southwest	92.8%	n/a	24.0%	n/a
UAL	80.3%	85.1%	42.5%	38.7%
US Airways	95.6%	80.0%	58.4%	37.8%

Table III
Total Capital, Including Aircraft Leases
(in thousands)

Carrier	Long Term Liabilities	Capitalized Leases	Equity
Alaska	1,431,200	664,758	569,700
American	19,746,000	8,491,917	947,000
America West	859,941	2,012,205	68,178
Continental	7,047,000	9,645,374	767,000
Delta	17,372,000	7,473,171	893,000
Northwest	11,729,000	5,182,180	(2,262,000)
Southwest	3,098,305	1,483,456	4,421,617
UAL	22,146,000	12,093,198	(2,483,000)
US Airways	9,215,000	5,058,638	(4,921,000)

Table IV
Capitalization and Ratio Analysis

Carrier	Long Term Debt/Total Capital		Total Debt/Net Worth	
	Without Leases	With Leases	Without Leases	With Leases
Alaska	71.5%	79.5%	3.83	5.19
American	95.4%	96.8%	28.20	37.16
America West	92.7%	97.7%	20.11	49.62
Continental	89.9%	95.6%	13.00	25.58
Delta	95.0%	96.5%	26.68	35.05
Northwest	NMF	NMF	-6.87	-9.17
Southwest	41.2%	50.9%	1.02	1.36
UAL	NMF	NMF	-10.53	-15.4
US Airways	NMF	NMF	-2.33	-3.36

NMF – not meaningful figure

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Using Simulations to Investigate
decision-making in Airline Operations

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Abstract

This paper examines a range of methods to collect data for the investigation of decision-making in airline Operations Control Centres (OCCs). A study was conducted of 52 controllers in five OCCs of both domestic and international airlines in the Asia-Pacific region. A range of methods was used including: surveys, interviews, observations, simulations, and think-aloud protocol. The paper compares and evaluates the suitability of these techniques for gathering data and provides recommendations on the application of simulations.

Keywords

In airline operations, decisions yielding optimal results may be the difference between company survival and bankruptcy. Stakes are high, timing is crucial, and the consequences of poor decisions could be critical. An airline's Operations Control Centre (OCC) operates in a complex, dynamic, and intense environment and serves as the airline's nerve centre. It is responsible for the control of aircraft to ensure economical, operational (Williams, 1967) and commercial efficiency. Although decision-making has been examined in the aviation industry, for example in Air Traffic Control (Corker, Pisanich and Bunzo, 1997), Pilot Crewing (Fischer and Orasanu, 1997), Schedule Disruption Management (Thengvall, Bard and Yu, 2000), and in Emergency Services (Flin, Stewart, and Slaven, 1996), empirical research on OCC decision-making is very limited. Understanding decision-making in OCCs requires the investigator to gain an appreciation of the demands presented by disruptions to operational schedules and the necessity to recover the situations, often under severe time constraints. A study of decision-making would require an investigator to be present 24 hours a day for many days, or even weeks in the international environment, to gain a full understanding of the work demands. Alternatively, an investigation would rely on the abilities of personnel to recall events and responses well after the disruption, exposing the investigation to inaccuracies. Consequently, studying decision-making in OCCs presents many challenges in terms of the study design. This paper examines and evaluates a range of methods for gathering data in airline operations.

Review of Data Collection Methods

Investigators face a difficult task in attempting to capture data accurately in a way that is methodologically sound so that generalisations can be made (Bordia and Rosnow, 1998). According to Zikmund (2000), the main primary data collection methods include surveys (including questionnaires and interviews), observation, and experiments. This paper examines the appropriateness of each of these methods for investigating decision-making in OCCs.

Survey

A common method of collecting data is the use of a survey (Sekaran, 1992) based on pre-determined questions. A survey can be widely distributed at reasonable cost and is an excellent basis for describing people's attitudes and behaviours (Shaughnessy and

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Zechmeister, 1994). However gathering information which relies on the recall of past events and behaviour may be of dubious validity and reliability (Foddy, 1994). Further, the current study was predicated on self-reflection by controllers and accurate analysis of events often well after the events occurred. There could be a lack of accuracy in recalling events, and confusion of details particularly where simultaneous disruptions occurred. A major weakness of surveys is that they are ill-suited for in-depth examination of the thoughts and feelings of individual respondents (Shaughnessy and Zechmeister, 1994). In addition, surveys do not provide the means to explore uncertainty or to clarify responses (Sekaran, 1992).

Interviews

The use of interviews as a method of data collection provides a means for establishing rapport with respondents, and exploring and understanding complex issues (Sekaran, 1992). Interviews allow researchers to adapt the questions as necessary, clarify doubts, and ensure responses are understood properly (Sekaran, 1992). Interviews also assist in understanding how individuals perceive and give meaning to certain phenomena or events (Berg, 1995). For example Yorkston, Klasner and Swanson (2001) used in-depth interviews to gain insider perspectives of communication by individuals (N=7) with multiple sclerosis. Yorkston et al (2001) found that this process of interviewing respondents yielded rich information. Interviews, therefore, may be useful for studying decision-making by controllers in OCCs as they allow a great deal of interaction between researcher and respondent. However there are limitations with interviews. Yin (1994) warns that interviews are verbal reports only, and are thus subject to bias, poor recall, and poor or inaccurate articulation. To address this issue in the current study interviews could be conducted during disruptions to elicit accurate and timely information but such action could interfere with the work process and controllers could be unwilling to cooperate. Even if interviews are conducted at a later time, the problems of accurate recall of details would still be a problem.

Observation

Observation in the work setting is useful to further understanding of the context or phenomenon (Yin, 1994) and establishes the validity of the findings. Observation enables

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researchers to distinguish between real and verbal behaviour (Bogdewic, 1999), and gather data at the time behaviour occurs (Atherton and Klemmack, 1982). In OCCs, observing disruptions as they occur permits the researcher to monitor the progress of the disruption and any actions being taken by controllers. Boote and Matthews (1999) found observation to be the most appropriate research methodology to observe customer traffic flows along main streets. Observational research requires no effort on the part of the respondent, and is a very effective way to enrich and supplement data gathered by other means (Boote and Matthews, 1999). However, attitudes and opinions cannot be recorded using observation (Zikmund, 2000). Systematic observation may be costly and very time consuming, and the lack of predictability of events may also create problems for researchers. For example in OCCs, observation may be conducted over several hours or even days without incident. Further, Zikmund (2000) noted several deficiencies with the collection of data using this technique such as observer subjectivity, memory limitations, inability to record all details, and inability to interpret observations such as body language, appropriately. Consequently in the current study observation alone would not capture the required information.

Think-aloud protocol

Think-aloud protocol is a technique for verbalisation, where participants are instructed to think aloud as they work on a problem (Woods, 1993). This technique allows the researcher to access the underlying thought processes, reasoning, and behaviours involved in analysing and solving the problem (Ericsson and Simon, 1993). Respondents in numerous studies have been asked to think aloud and talk through their thoughts. For example de Groot (1978) presented chess players (N=22) with various combinations of chess pieces on a board, and asked the players to think aloud while selecting the best move. De Groot (1978) noted that most subjects found thinking aloud, slowed thinking down, and made the subject think more explicitly. Think-aloud protocol may be appropriate to gain an insight of controllers' thought processes in decision-making. However, controllers do not have time during actual disruptions to elucidate their reasons for taking particular actions.

Methods for recording responses

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Various methods and devices can be used to record responses, such as tape recordings of dialogue, written responses, computer inputs, observations, or by some combination of these approaches. However the method used may influence the results. For example having participants respond in writing may be tedious and limiting. Adelman, Tolcott and Bresnick (1993) examined the effect of gathering data on quality judgement with trained Army Air Defence personnel (N=63), and concluded that the artificialities of the paper and pencil task may have influenced the results.

Case study approach

The case study method is well suited to exploratory or descriptive studies (Yin, 1994). The multiple case study approach has the benefits of deepening the understanding of the subject (Miles and Huberman, 1994), enabling more information to be gathered and increasing the generalisability of the research (Bryman, 1989). Using a case study method would allow the investigation of decision-making in several OCCs. The case study method may be limited due to the necessity to gain access to (Burgess, 1984), and cooperation of (Zikmund 2000) a number of suitable companies, and to the time taken to complete the study (Yin, 1984).

Experiments and simulations

In an experiment, variables may be manipulated in controlled conditions to test a hypothesis (Zikmund, 2000). Often comparisons are made between results from a control group and an experimental group (Burgess, 1993). A simulation is akin to an experiment; specially created in an artificial setting, but not very different from reality (Sekaran, 1992). One of the most important aspects of simulation is its ability to mimic reality so that researchers can study phenomena too difficult or impossible to study in real life (Bordt, 1999). The use of simulation is also recognised as one of the most widely used techniques in operational research and management science (Law and Kelton, 1991). The ability to control the simulation allows the replication of situations, and the manipulation of certain conditions (Blank, 1984). These aspects were important considerations in the current study.

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Simulations have wide applications in research and practice. Simulation has been used as a decision support tool for management. For example, in a study of operational changes in an army hospital, simulation was used to assess alternative patient capacity and staffing capabilities (Ledlow and Bradshaw, 1999). Simulation may also be used in a teaching or training context. According to Salas and Burke (2002), simulation may be effective provided that it is instructional, meets task, performance, and feedback needs, and helps to guide learning. Bordt (1999) found simulation to be a very effective teaching aid to students studying criminology, because the students became fully engaged in the process, could readily test real life situations, and demonstrated critical evaluation skills. Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy, and Brock (2002) used simulation to test a PC-based driving skills program with young drivers (N=45). Simulation provided a safe environment to study the effects of experience and risk awareness on drivers.

In aviation, one of the most useful applications of simulation is the flight simulator which allows the representation of aircraft flight with safety, training, and financial efficiencies (Moroney and Moroney, 1999). Simulation is also used extensively in Air Traffic Control, particularly for selection and training (Ackerman and Kanfer, 1993). The conclusion from the use of simulation in these domains is that where appropriately designed and used, simulation can be a most effective tool for testing, teaching, and learning. The suitability of simulations as a data collection method relies on the degree to which the simulation replicates the work situation. Therefore it is important to pay attention to detail in the design of simulations.

In summary, all the methods of data collection considered have limitations. Therefore, collecting data through multi-methods, although costly and time-consuming, lends rigour to research (Sekaran, 1992). The current study combined a number of data-collection methods to counter the deficiencies of any single method. This paper focuses on data collection methods and therefore the substantive findings are not reported in the paper.

Data collection in the current study
A survey was distributed as a preliminary test to controllers (n=6) from one Australian domestic OCC. Respondents were asked to complete a questionnaire at the conclusion of

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each disruption or at the end of each shift. Questions asked respondents to record the nature, cause and duration of each disruption. Respondents were asked to answer questions such as 'where did they obtain information for decision-making', and 'what amount of information did they need to make decisions'? Qualitative data were also collected by observing controllers during disruptions and asking unstructured and semi-structured questions.

However the use of surveys and observations to collect data about decision-making during disruptions was inappropriate. The frequency, regularity, and duration of disruptions were unpredictable, making data collection inefficient. Some disruptions continued across a number of shifts or even days. Therefore, decision-making processes of any one respondent were difficult to capture. Second, respondents were generally unable or unwilling to answer questions during a disruption as they needed to focus intensely on solving operational problems. Third, there was no way to compare the decision-making outcomes of respondents. Some disruptions were resolved quickly and with minimal decision-making from controllers, while others were longer and required extensive decision-making. Fourth, if a number of disruptions occurred simultaneously, decision-making relevant to any particular disruption could not necessarily be determined. Fifth, there was no means by which the researcher could be confident that respondents completed the questionnaire with any degree of accuracy or timeliness. The conclusion reached was that the method using surveys and observation to study decision-making in an OCC was inappropriate.

Simulation study
The study was re-designed using a multiple case study approach to examine decision outcomes of controllers (N=52) in five Operations Control Centres. The study was broadened to include OCCs in other Australian domestic airlines, as well as OCCs of international airlines in the Asia-Pacific region. One airline operated solely domestic services, two operated solely international services and two operated both domestic and international services. In domestic operations, flight stages are short, aircraft are scheduled to operate a high number of flight stages in a day, and are on the ground for short durations between flights. Controllers handling domestic disruptions, therefore, make numerous

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decisions within very short timeframes. In contrast, international flight stages may be very long, aircraft may only operate a small number of flights per day, and are on the ground between flights for longer durations. Decision-making therefore is generally less intense.

A simulation to replicate each of the operational environments was designed in collaboration with a panel of experts. The experts were current or retired senior operations managers (N=10). For each simulation, hypothetical flight schedules were constructed to replicate typical airline schedules. Each simulation consisted of a visual display showing a coloured utilisation of a fleet of aircraft, and was laminated to allow respondents to write or draw on the surface. The display was a close representation of the computerised display normally used by operations controllers. Information on the display included aircraft flight stages with flight numbers, city pairs (routes), flight loadings, maintenance unserviceabilities and requirements, and other relevant information. The flight stages were positioned on the display according to a continuous time scale. A time-line could be positioned along the time-scale to indicate the specific time of day, or a passage of elapsed time.

Domestic Simulation
The domestic simulation was designed for OCCs in the Australasian region. Hence the flight schedule was constructed for a hypothetical airline operating within Australia. The base location of the airline was irrelevant for the study.

International Simulation
The international simulation was designed for OCCs in the Asia-Pacific region. Hence the hypothetical airline was based at a fictitious location, but within the Pacific region. Information for respondents included the approximate location depicted on a map, and the local time zone of the location. Respondents could determine the flying time and therefore distance to any destination of the airline from the flight schedules.

A series of simulation scenarios was designed in collaboration with the panel of experts. The scenarios consisted of three typical operational problems for each of the domestic and international operations, and each successive scenario was more complex than the previous

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one, in terms of the nature of the disruption, the consequences of any decision, and timeframes for decision-making. The three scenarios were completely independent of each other. A short audio briefing tape was made for each of the domestic and international simulations. The tape served to ensure a consistent briefing for each respondent, and contained important information for the simulation. The preamble outlined the reason for the study and emphasised to the respondent that the study was concerned with decision-making processes rather than solutions to the scenarios. Respondents were asked to think aloud as the simulation proceeded.

The simulation was conducted between the researcher and one respondent at a time at the respondent's workplace, but in a separate room. Respondents were invited by their managers to participate voluntarily in the study. As only three OCC controllers from three different airlines declined the study, the sample was highly representative of the population of controllers in the airlines studied. While large sample sizes are more reliable, they are also more costly (Blank, 1984). The study was limited to the Asia-Pacific region for this reason. In the OCCs of the two airlines in the study that operated both domestic and international operations, respondents worked either as domestic or international controllers. These respondents were permitted to select either the domestic or international simulation.

Prior to running the simulation, each respondent listened to the five minute audio briefing tape. Respondents were asked if any information required clarification or whether they felt they needed additional information. When respondents indicated their readiness to commence the simulation, the tape recorder was set to record all subsequent communications. Taping is more accurate than any other method of recording interview data, providing the respondent agrees to being taped, and the taped data are transcribed (Yin, 1994). The current study satisfied both these criteria. The taping process did not appear to present any difficulties and the respondents did not react adversely to the tape recorder, even to the extent of waiting while tapes were changed. According to Ericsson and Simon, (1993) respondents become so involved in the task that they soon become accustomed to the presence of the taping device.

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The researcher commenced the simulation by showing respondents the utilisation of flight schedules and describing the display. The respondents were asked to familiarise themselves with the utilisation, and communicate observations and any questions to the researcher. As each scenario was introduced, respondents were asked to think aloud as they attempted to solve the operational problems. The researcher played two critical roles throughout the simulation. The main role of the researcher during the simulation was to control and direct each scenario according to a script. As the scenario progressed, further information was given to respondents at appropriate times. Typical developments included sudden maintenance failures, deteriorating weather conditions, or particular commercial requirements. Second, the researcher acted as a resource base for the scenario, providing any information required by respondents as the scenario progressed. On request from respondents, the researcher provided information or answered questions relating, for example, to crew availability or roster commitments, passenger connections, airport or air traffic control related information, maintenance requirements, and weather advice.

As each scenario progressed, respondents were required to make decisions and attempt to construct solutions to the operational problems. By observing respondents' actions, and listening to their verbalised thought processes, the researcher could explore the decision-making process. For example if a respondent noted several flights with low loadings (proportion of booked passengers, to available seats), the researcher could probe the reason for the respondent's comment. The researcher also asked questions such as 'why do you doubt the information provided by Engineering?' or 'how do you know when you have enough information to help you make a decision?' The scenario was continued until respondents considered a problem was solved satisfactorily or the researcher considered little would be gained by extending the scenario.

Discussion

Most respondents were familiar with details contained within the simulated displays. However, respondents working in OCCs outside Australia, but participating in the domestic simulation, required clarification of information such as Australian airport abbreviations. Respondents were asked to treat the initial familiarisation of schedules as akin to

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commencing a normal shift. The researcher provided a briefing (handover) to facilitate this process.

Respondents described their thought processes throughout the simulation and readily offered comments or answered questions as the scenarios progressed. Periods of silence did not suggest disinterest or loss of awareness of the scenario. During these periods, the researcher prompted respondents to verbalise their thoughts by asking questions such as 'what are you looking at'? or 'why are you indicating this flight'? Respondents became totally absorbed in the scenarios. At times the researcher had to clarify flight numbers or aircraft identifications to ensure the tapes could be transcribed accurately.

Preliminary findings

The influence of respondents' experience in other areas of the airline became apparent in their approach to tackling the task. For example, respondents who had a crew rostering background tended to give priority to crew-related problems during the scenarios. Similarly respondents who had experience in airline ground-handling roles, attended initially to issues such as airport congestion or potential aircraft handling problems. These preliminary findings suggest that a controller's previous experience, particularly in areas outside OCCs may influence the decision-making process. The findings should not be seen necessarily as negative but may imply that OCCs need to be aware of the influence of controller background.

Participant response

Respondents reported that they enjoyed participating in the simulation. One respondent (Male, 41-50 yrs old, 2 years experience in OCC) who participated in the domestic simulation commented that he felt he should be reaching an immediate solution, but in the absence of co-workers, was unable to solve the scenario.

Management response

Management in the five OCCs participating in the study commented very favourably on the use of the simulations. None of the OCCs conducted simulations that investigated decision-making outcomes of controllers prior to the study. Managers suggested that the

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simulation method may provide OCCs with a valuable tool for selecting suitable staff, and as a means of identifying staff development and training opportunities.

Data collection methods in the current study

The use of simulation in the current study provided a suitable means of investigating decision-making of controllers in OCCs. However simulation alone would not have yielded the degree of richness of information that was collected. The necessity to interact with participants and observe their behaviour as they made decisions was a critical aspect which contributed to the success of the data gathering method necessary for the study. The simulation also provided a suitable context in which respondents could verbalise their thoughts. In contrast, other individual methods of data collection fail to capture the degree of data necessary for an in-depth investigation of decision-making. The study emphasised that the use of simulation in conjunction with observation, interviews and think-aloud verbal protocol was the most appropriate combination of methods to study decision-making in OCCs.

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Conclusion

The study represents a preliminary investigation of the application of several methods of data collection in OCCs. A conclusion drawn was that no one method was sufficient to investigate controller decision-making. However a multi-method approach using simulation together with observation, interviews and think-aloud protocol provided a most appropriate means. The full results of the study should make a substantial contribution to the research to gain further understanding of thought processes behind OCC decision-making. The simulation method has wide application and should lead to the development of an appropriate management tool to identify selection and training opportunities, and measure performance of controllers in OCCs. The current study strongly lends itself to the development of a computer-based simulation.

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